



Effects of Insulation on Basement Walls

A RESEARCH REPORT

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A Survey of the Statistical Incidence of
Problems, Together with an Evaluation of
the Technical Processes

Sponsored by the
Energy Conservation Branch
Energy, Mines and Resources Canada

Prepared by
M. Kani of Allen-Drerup-White Ltd., Toronto
J. Timusk and K.D. Pressnail of the
University of Toronto
E. Scheuneman and M. Tremayne of BETT, EMR

Edited by
D. Eyre, Saskatchewan Research Council

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For further information on the BETT Program please contact:

The Buildings Energy Technology
Transfer (BETT) Program
Energy, Mines and Resources Canada
580 Booth Street
Ottawa, Ontario
K1A 0E4

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A survey has been conducted to determine the incidence of foundation problems caused by foundation retrofit, and to determine the types of problems that are occurring. The findings are based on the responses of 148 municipal building officials and 102 specialists in this field, and are supported by supplementary studies dealing with the statistics of retrofitted basements and the state of the art relating to foundation problems. The incidence of retrofit-induced foundation failure is very low, in fact lower than the incidence of foundation problems arising from conventional construction practice. Two main types of problems were found to be significant: potential moisture problems at the top of foundation walls; and structural problems caused indirectly by frost heave under adjacent unheated garages. There is no significant evidence of foundation problems resulting from the direct effects of frost heave and adfreezing.

* * *

On a effectué une étude visant à déterminer la fréquence et le type des problèmes occasionnés par l'amélioration thermique des fondations. Les conclusions de cette étude s'appuient sur les réponses de 148 responsables municipaux du bâtiment et de 102 spécialistes de la construction, et sont étayées par des études statistiques sur l'amélioration thermique des sous-sols et par une documentation technique de pointe sur les problèmes de fondations. La présente étude révèle que les dommages causés aux fondations à la suite de travaux d'amélioration thermique sont très rares et que les problèmes de fondations sont en fait plus fréquents dans les constructions de type classique. Malgré tout, on a retenu deux types de problèmes jugés importants. Il s'agit, d'une part, de problèmes d'humidité qui peuvent se présenter dans la partie supérieure des murs de fondation et, d'autre part, de problèmes de charpente causés indirectement par le soulèvement dû au gel en-dessous d'un garage non chauffé attenant à une maison. À noter que l'étude ne révèle aucune preuve tangible de problèmes de fondations directement imputables au soulèvement ou à l'adhérence dus au gel.

Le lecteur trouvera un sommaire du présent rapport, en français, à la page iii.



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This report is issued by the Buildings Energy Technology Transfer Program (BETT) of Energy, Mines and Resources Canada, in the belief that it usefully and significantly advances the state of the art. In doing this, BETT does not necessarily endorse the findings or views expressed herein.

The primary aim of BETT is to support the development and evaluation of energy-efficient building technology and effectively transfer the proven technologies to the end user. But in a time of rapid change things do not always go according to plan; technologies are implemented -- sometimes extensively -- before they have been fully proven. In such situations, building scientists have been called upon to identify potential problem areas and forewarn the implementers. But if these predicted problems are not validated through R&D they may sometimes take on a life of their own, acquiring a currency and a weight that is totally undeserved and illfounded in fact. Thus, in recent years, an entire mythology of dire predictions has arisen around the technology of retrofit -- partly justified, partly not.

The study described in this report was started in 1984, when it was generally believed that basement retrofit might promote an accelerated impairment of the basement by aggravating such problems as frost heave, adhesion freezing and moisture balance. Subject to some residual uncertainties about induced moisture problems, the study has shown that the original perceptions were largely incorrect. But to arrive at this conclusion it was first necessary to sort out a tangled web of misconception and misdiagnosis -- often with the one supporting the other. This could not have been done without confidential access to recent research findings at the University of Toronto. The report is therefore of technical value, but the astute reader will not miss the message concerning scientific speculation and its potential for misuse.

D. Eyre (Editor)
Saskatchewan Research Council
July 1985.

Le présent rapport porte sur les problèmes de fondations qui résultent de l'application des techniques d'amélioration thermique des sous-sols. Les données sur lesquelles il s'appuie proviennent de trois sources. La première est une enquête effectuée pour le programme TTEB d'EMR en 1984, qui compile les réponses de 148 responsables municipaux du bâtiment et de 102 spécialistes de la construction. La deuxième source est constituée d'une documentation technique de pointe et d'un certain nombre d'études réalisées à l'Université de Toronto. Enfin, la troisième source comprend des données statistiques et des rapports de suivi détaillés, effectués sur des cas problèmes dans le cadre du programme TTEB d'EMR.

Sur les quelque 2 millions de sous-sols qui ont fait l'objet de travaux d'amélioration thermique au Canada, l'étude de 1984 ne dénombre que 50 cas problèmes, dont une bonne partie ne sont pas pleinement avérés. Si le pourcentage de cas problèmes était celui que pensent certaines personnes, même une étude bon marché aurait fourni des données plus probantes. On en a donc conclu que l'étude en question donnait un reflet fidèle de la réalité et que le pourcentage de cas problèmes était remarquablement faible.

Les problèmes ne semblent pas se manifester dans les sous-sols, et les renseignements dont on dispose actuellement portent à croire que les méthodes d'amélioration thermique des sous-sols ont en général beaucoup plus d'effets favorables que néfastes, même si cela n'exclut pas certaines difficultés à l'occasion.

On a pu trouver pour seulement quatre cas des données suffisantes permettant de déterminer la cause du problème. Dans le premier cas, la méthode de construction ne respectait pas les normes, dans un autre, il s'agissait d'un cas typique de dommages causés par l'humidité au point de rencontre de la charpente de bois et du mur de fondation, et, enfin, les deux derniers révélaient des dommages au mur de fondation à la suite du soulèvement et de l'adhérence dus au gel (à noter cependant que ces deux derniers cas ont été observés dans des conditions extrêmes qui sont rarement réunies).

L'étude conclut que le phénomène d'adhérence ou de soulèvement dû au gel occasionne rarement des dommages au sous-sol, qu'il soit isolé ou non. S'il y a exception, elle est imputable aux effets indirects du soulèvement dû au gel, qui se transmet au mur de fondation par le truchement de structures attenantes non chauffées, comme les garages. On a pu identifier avec plus ou moins de certitude quelques cas de ce genre.

Cette conclusion est corroborée par des recherches récentes (et encore inédites) effectuées à l'Université de Toronto, qui jettent un éclairage nouveau sur les phénomènes de soulèvement et d'adhérence dus au gel et en diminue la responsabilité dans les problèmes de fondations.

Malgré les résultats de notre étude, il est prudent de laisser une certaine place au doute. En effet, les techniques d'amélioration thermique des sous-sols n'existent que depuis quelques années. Certains problèmes peuvent ne pas encore être apparents et ne pourront être observés qu'au bout de plusieurs années. Autrement dit, même si l'étude ne révèle qu'un cas démontré de problèmes d'humidité, il se peut qu'il y en ait d'autres à l'état latent. À cet égard, une étude technique annexée au rapport recommande la prudence pour l'isolation intérieure des solives dont les extrémités sont encastrées dans une maçonnerie massive.

Le rapport intègre également une étude technique des effets de l'isolation partielle d'un sous-sol, qui préoccupe certains spécialistes du bâtiment. En effet, quand l'isolation n'est appliquée que sur une partie du mur du sous-sol, il y aura des différences de température sensibles entre les parties isolées et non isolées, ce qui risque, pense-t-on, de créer une contrainte thermique pouvant endommager les murs. L'étude conclut cependant que ces effets seraient négligeables.

Since its inception in 1977, the Canadian Home Insulation Program (CHIP) has gradually increased the range of retrofit options covered under the Program. Starting with basic retrofit insulation techniques, the range is now being expanded to include such things as airtightness sealing and foundation insulation.

Foundation retrofit techniques, if widely adopted, will have a considerable impact on residential energy conservation. It has been estimated that more than 95% of Canada's existing houses and low-rise apartments have a full basement, in one form or another. These basements account for typically 10% to 30% of the total heat losses from the unit, and with good retrofit techniques this heat loss can be typically reduced by a factor of three. The potential for energy conservation is therefore high.

Unfortunately, foundations are a major source of problems in the existing housing stock. The problems range from surface deterioration to major structural damage and have a variety of causes, including soil reaction, inadequate drainage, low quality of construction, etc. Existing foundation practises therefore have a built-in vulnerability, and this has two important consequences for foundation retrofit. First, a defective foundation may impose severe limitations on the types of retrofit that should be attempted; in extreme cases it may be inadvisable to proceed with any type of retrofit. Secondly, the retrofit work may increase the vulnerability of the foundation to structural damage; it may aggravate an existing problem or it may create a problem where none previously existed. This, at least, is the conventional wisdom - a wisdom that is brought into question in this report. Timusk (referenced later) points out that, in some extreme cases, retrofit can have a remedial effect by taking the freezing isotherm out of a basement wall and lowering the relative humidity of the wall - a common procedure with brick walls that suffer freeze-thaw damage.

This report is concerned only with foundations where an applied retrofit has created new problems or aggravated existing ones.

At the present time there are suspicions that foundation retrofit will increase the risk of foundation problems. These suspicions have arisen mainly from speculations in various technical papers, such as those in references 1 to 4. The word "speculation" is used deliberately, since in many cases there is no supporting factual information. From the existing knowledge of physical processes in and around a foundation, we can propose a number of ways in which retrofit techniques will worsen an existing problem or create a new problem. Such speculations are both useful and desirable in that they tell us to proceed with caution, but they do not allow us to quantify the risk. Thus, while recognising that the prevailing ideas are reasonable and that problems are possible, we have no feeling for the scale or severity of the problems in practise. We cannot say if the problems will be serious or trivial in terms of actual number of houses affected.

In planning a program of foundation retrofit it is useful to know if there are any perceived problems or not, but a sensible strategy can be devised only if we have some idea of the scale of the problems. Unfortunately, research has not been extensive enough to give us specific guidance, and we are obliged to depend on site experiences.

A number of unauthenticated cases - scarcely more than rumour - have conditioned us to expect a significant increase in foundation problems after retrofit. In tracking down these problems we must face the difficulties of information flow in the field of retrofit. To date, practically all examples of foundation retrofit are to be found outside government programs. The work has been conducted independently by contractors or homeowners, using techniques that are essentially untested. Problems may have occurred, but there is no coordinated process for bringing

these problems to the attention of interested agencies. Furthermore, it is likely that the design details and the original condition of the foundation will be poorly documented, making it difficult to establish the true cause of the problem several months or years after the retrofit.

This report addresses these issues. It describes a survey of the Canadian housing stock, in which an attempt has been made to identify and evaluate all instances of foundation problems that could conceivably have been caused or aggravated by retrofit practises. The primary objective was to get a rough indication of the incidence of these problems, as an essential factor in the planning of future retrofit programs. If, on the one hand, the incidence of foundation problems could be shown to be high, this would indicate a need for further evaluation and development before proceeding with widespread application of the practises. On the other hand, if the incidence could be shown to be low, this would indicate that existing practises should be promoted, but with a modicum of caution.

The contents of this report are the result of three separate but related activities:

- The main activity was a Canada-wide survey of foundation failure, conducted by Mr. M. Kani of Allen-Drerup-White Ltd. of Toronto.
- Under a small contract, Dr. J. Timusk and Mr. K. D. Pressnail, of the University of Toronto, have submitted information on the building science aspects and on the interpretation of the survey findings.
- Mr. E. Scheuneman and Mr. M. Tremayne, in their capacity as technical analysts with the BETT program, have conducted a brief study on the available statistics relating to foundation retrofit, and have conducted a more detailed investigation of the facts relating to some of the poorly authenticated cases of foundation failure.

This report is based primarily on the procedures and findings of the Allen-Drerup-White study. The contributions of the University of Toronto and of Scheuneman and Tremayne are introduced at relevant points in the text.

2.1 The Allen-Drerup-White Study

The primary objective was to identify all cases in the Canadian housing stock in which foundation problems could conceivably have been caused by foundation retrofit techniques. Cases were to be identified by consulting with all agencies who might have some exposure to this type of problem.

The secondary objective was to authenticate and evaluate all cases identified by the above process. Attempts were made to document the conditions that

could have influenced the problem, then, using this as a basis, attempts were made to define the cause or causes of the problem.

Some consideration was given to the reliability of the sources of information. It was recognised that foundation damage is not always visible or immediately detectable, and that there may be many undetected, and therefore unreported, instances. At the same time a reported case may not have been followed through or recorded to the degree required for this study.

For strategic reasons a number of limitations were placed on the survey. It was to deal only with:

- foundations of poured concrete, block wall or brick construction,
- foundations which displayed problems after retrofit but not before,
- "deep" foundations, with footings below the frost line,
- foundations that had been retrofitted by the addition of insulation on either the inside or the outside.

2.2 Information from the University of Toronto

Concurrently with the above study, the University of Toronto has been conducting its own research on the phenomena of frost heave and adhesion freezing around residential foundations. The research has been conducted by K. D. Pressnail under the supervision of Prof. J. Timusk and is reported in Pressnail's M.Sc. Thesis (11), which became available in draft form in January 1985.

This thesis explores the processes of frost heave and adhesion freezing, and constitutes an advance in the state of the art. It questions the validity of the

prevailing ideas about these processes and their effects on foundations, which are based on an extrapolation of Penner's work (7) on steel pipes, and shows that this extrapolation is not justified.

Pressnail's work has a considerable impact on this report, particularly in the matter of interpreting the results of the Allen-Drerup-White survey. Unfortunately, Pressnail's thesis has not yet appeared in the technical literature and it would be improper to release his findings pre-emptively in this report. The underlying dilemma has been resolved by adopting the following compromise (an editorial decision): Pressnail's work will be referenced where it relates to statements or interpretations in the report, but the substance of Pressnail's work will not be entered into the report.

The relevant interpretations have been defined by the University of Toronto, under the terms of the small contract mentioned above. In addition, the University has submitted technical appreciations on moisture problems in embedded joists and on the potential risk of foundation failure arising from thermal stresses induced by partial retrofit. These appreciations are reproduced almost entirely in two chapters of the report. The University has also conducted a more detailed investigation on some of the poorly authenticated cases of foundation failure - as revealed by the Allen-Drerup-White study - and has been able to define the actual causes of failure.

2.3 Investigations by Scheuneman and Tremayne

In assessing the seriousness of retrofit-induced foundation problems, in terms of the number of occurrences, it is important to have some idea of the number of insulated basements in the Canadian housing stock. The Allen-Drerup-White study gave an unconvincing estimate of this number - mainly because of the inherent limitations in the low-cost sampling technique. Accordingly, Scheuneman has conducted a brief investigation of the statistics available

through other sources. His findings are presented separately in Section 6.

Scheuneman and Tremayne have also collaborated with the University of Toronto in the investigation of some poorly authenticated cases of foundation failure.

Before designing the survey procedures it was considered essential to define the various types of problem that could be caused or aggravated by foundation retrofit. This information is adequately covered in many of the papers given in the reference section and a brief review is therefore sufficient for the purposes of this report.

3.1 Moisture in the foundation structure

Foundation structures contain a number of paths for admitting moisture and a number of paths for dissipating it. Inside the foundation structure, moisture can move by the processes of diffusion, gravity and capillarity (wicking), as well as hydraulic flow through cracks. Retrofit techniques, consisting of the addition of insulation to the inside or outside of the foundation wall, can affect the balance of these various processes - sometimes beneficially and sometimes to the detriment of the foundation. The following potential problems have been identified:

- Some retrofit techniques may cause increased moisture content at the top of the foundation wall, either by assisting the wicking action or by inhibiting the moisture dissipation processes at this point. This may initiate a process of wood rot at the sill plate. The effect will be most pronounced when mortar is present, as in block, brick or rubble walls, but may not be visible until the deterioration is well advanced. When joist ends are embedded in solid masonry walls, moisture problems are of particular concern and the practise of applying insulation between joists is strongly disapproved. This important topic is discussed in detail by Timusk in Chapter 8
- When a foundation wall is insulated on the interior, the wall will be deprived of heat from the house and will be more vulnerable to climatic temperature variations. Moisture in the wall, when

subjected to freeze-thaw cycles, could lead to cracking and spalling of the structure.

- When a foundation wall is insulated on the interior, the new structure will inhibit the dissipation of wall moisture into the house air. Under some circumstances, free water or a saturated vapour pressure condition could be established inside the new structure, perhaps causing rot of wood frame components. Again, this may not be visible until the deterioration is well advanced.

3.2 Soil reaction

Some soils, depending on drainage and soil type, become very active under a combination of high moisture content and below-freezing temperatures. Around an uninsulated foundation this effect is usually moderated by heat flow into the surrounding soil, but when the foundation wall is insulated - either on the inside or outside - this moderating effect is reduced and the soil may become more active. The following problems could occur as a result of foundation retrofit:

- Frost heave at the footings could cause structural damage to the foundation wall. In this study, the terms of reference exclude this type of problem.
- Increased frost heave, in the form of ice lensing near grade level, could cause lifting of paving such as sidewalks and driveways.
- Ice lensing, in combination with adhesion freezing to the foundation wall, could exert an upward force on the foundation wall and cause structural damage. This 'hypothesis' appears to have achieved wide currency in the technical and building communities. It will need to be re-assessed in the light of Pressnail's recent work (11).

3.3 Changes in drainage

Foundation retrofit involves thermal and mechanical changes that can affect the performance of the drainage processes around the foundation and cause damage through hydrostatic effects. The following problems fall into this category:

- Frost penetration is deeper around an insulated basement and may inhibit the drainage process. The worst case occurs when frost penetrates to the footing and the weeping tile system, causing a major impairment of the drainage process. However, this case is excluded by the terms of reference of this study.
- When porous insulation is installed on the outside of the foundation wall it may act as a drainage channel for water flow. Timusk observes that laboratory and field experience clearly shows this to be beneficial. However, there are some residual concerns about what might happen if there is a departure from good practise, particularly if there is a poor coupling between the weeping tile system and the drainage effect of the insulation. Under these conditions the porous insulation might deliver surface water (as distinct from groundwater) to the weeping tile system faster than it can be carried away. In this situation there is a theoretical risk of the kinds of major structural damage (floor uplift, etc.) that have been encountered in poorly drained houses surrounded by a high water table. Also, the foundation wall may be exposed to free water under hydrostatic pressure, and the existing damp-proofing (if present) may not be an adequate barrier against moisture penetration. This concern appears to be reasonable, though there is no evidence that it has occurred in practise.
- If the drainage processes are impaired by any of the above factors - a remote possibility - then it should be noted that the consequences are particularly severe when the surrounding soil consists of expansive clays. Soil expansion, under the action of high water content, could induce severe

vertical and lateral loadings on the foundation wall and floor slab.

3.4 Thermal Strain Effects

When only part of a foundation wall is insulated, temperature differences between the insulated and uninsulated parts may set up thermal stresses severe enough to cause foundation damage. This potential source of problems was not explored in the Allen-Drerup-White study. In Chapter 9 Timusk gives a detailed discussion of this effect and argues that significant foundation damage is unlikely.

3.5 A symptomatic approach

The above review is useful, in that it establishes the various types of problems that may be encountered. But in the following survey it is unlikely that the individual respondents would be able to identify problems to this degree. For the purposes of the survey it was therefore decided to adopt a symptomatic approach, based on the following categories of problems:

- Wall damage:
Consisting of either localised or extended structural damage or impairment.
- Material deterioration:
Consisting of crumbling of masonry elements, serious brick spalling, rot of wood components, etc.
- Surface deterioration:
Consisting of minor surface effects, including efflorescence on masonry surfaces, discolouration of drywall and panelling, etc.
- Moisture-related:
Consisting of mould, mildew, rot and odours.
- Retrofit-related:
Consisting of deterioration of the retrofit components, including degradation of insulation, failure of fastening or support systems, etc.

4.1 Design considerations

The design of a survey, and its subsequent effectiveness, are determined largely by the budgetary and scheduling constraints imposed on it. In this particular case the survey was to be conducted within fairly narrow constraints, and the survey procedures had to be designed to elicit the maximum amount of information within a short time and small budget. The problems were resolved into three factors:

- Identifying and selecting the survey sample, so as to cover all the most likely sources of information.
- Designing the survey questionnaire and procedures to produce the right kind of information, with follow-up to ensure a good survey response.
- Establishing follow-up procedures to validate, assess and interpret problem cases.

These are discussed under separate headings in the following text.

4.2 Selecting the survey sample

Ideally, one should attempt to make contact with the occupants of all houses with retrofitted foundations. However, there are obvious difficulties in doing this and it cannot be achieved within a small budget. Somehow, the required information must be got by dealing with a smaller and more easily accessible sample of respondents.

It was argued that, if problems were occurring as a result of foundation retrofit, many of these problems - but not necessarily all of them - would have been brought to the notice of municipal housing

authorities or other agencies concerned with housing quality. It was therefore decided to direct the survey at a selection of municipal building officials, government housing and energy departments, builders' associations, researchers and individual engineers and contractors.

The sample of municipal building officials was determined by identifying all municipalities with populations greater than 5,000. This gave a total sample of 551, comprised of 379 English-speaking and 172 French-speaking municipalities.

The second part of the sample was of national scope, consisting of specialists from government agencies, builders, researchers, etc. These were identified by telephone contact, discussion and referral. This sample finally consisted of about 100 specialists, whose names and affiliations are listed in Appendix A.

4.3 Survey procedures

The first objective was to identify the known cases of foundation retrofit problems, and to determine the percentage incidence of these cases among retrofitted foundations. For this exercise it was found convenient to divide the survey sample into three categories, each requiring a different method of approach:

- Municipal building officials in English-speaking communities (379) were to be sent a short questionnaire.
- Municipal building officials in French-speaking communities (172) were to be sent a short form letter in French. Within the cost constraints of the study it was considered impracticable to develop a French version of the questionnaire.
- Specialists were to be contacted by telephone, using referrals and recommendations to identify further contacts (final total of about 100).

Appendix B consists of the questionnaire sent to English-speaking municipalities. It was kept as short as possible to secure a good response, and its main purpose was to gather the necessary statistics on foundation problems. Arrangements were built into the questionnaire to allow follow-up on relevant cases of problems in retrofitted foundations.

Appendix C consists of the form letter developed for French-speaking municipalities. The intention was to discover if any relevant problems had been encountered. If so, it was proposed to follow-up by telephone.

In the telephone survey, the 100 specialists were asked the question "Are you aware of any specific cases where an insulation retrofit caused or aggravated basement problems?". Positive responses were followed up, and the specialists were invited to offer any views or comments on this problem area.

It was recognised that this survey procedure might not be totally effective in identifying all cases of foundation retrofit problems; it was quite possible that some problem cases would not have been brought to the attention of any of the surveyed agencies or specialists. To deal with this eventuality, a letter of request was circulated to a small number of newspapers and journals for publication. The text of the letter is given in Appendix D.

4.4 Follow-up procedure

The responses from the above survey contained a number of references to specific problems in retrofitted foundations, some of which could be ruled out as being outside the terms of reference of this study. The remainder appeared to be relevant, and the

next step was to document the problem in greater detail, using a more detailed questionnaire.

The detailed questionnaire was prepared in draft form, and was circulated to a small panel of reviewers for comment and revision. Its final form is given in Appendix E. Copies were circulated to all those respondents who had identified a relevant problem, and in some cases this was followed-up by telephone.

When all the information had been received and collated, an expert on foundations was engaged to assist in assessment and interpretation.

5.1 Response statistics

Of the 379 questionnaires sent out, 157 were returned. Seven of these were blank and two dealt with irrelevant problems, leaving 148 usable responses. The 40% response can be considered good in a survey of this type.

From the 172 letters mailed to French-speaking municipalities, only two responses were received. It should be noted that only positive replies were solicited, therefore it is difficult to know whether the low response is an indication of lack of problems or indifference on the part of the people sampled.

The letter circulated to newspapers and journals appeared in two publications (see acknowledgements). Seven responses were received, but only three were relevant.

It was not possible to contact all the specialists originally listed. Some were unavailable for one reason or another, and in such cases a close colleague was contacted. Altogether, responses were obtained from 102 specialists.

On conclusion of the above surveys, fifty potential problem cases were identified, involving fifteen respondents. Fifty questionnaires were circulated to these respondents, but only four completed questionnaires were received. Telephone follow-ups did not improve the situation; many respondents pleaded lack of time and one did not wish to make detailed comments on a case that had been under litigation.

5.2 Questionnaire analysis

Some respondents had difficulties in interpreting questions and instructions, and responded in ways that were not anticipated when the questionnaire was designed. Some responses were in terms of total numbers, some were in numbers per year and some were expressed as percentages. The responses therefore lack coherence in the type of information given, making it difficult to conduct a meaningful statistical analysis.

A detailed collation of the 148 usable responses is given in Appendix F. Table F.1 consists of a count of the usable responses to each question. Table F.2 consists of a simple statistical analysis of the responses, including the maximum, minimum, mean and median values. It has been found convenient to group the information according to the responses to questions 3 and 6, which deal with the total population of basements and the number of problem cases in retrofitted basements. These two questions, together with question 5, determine the incidence of problem cases in retrofitted basements. The grouping system is explained at the beginning of Appendix F.

The analysis on page F.5 demonstrates the crudeness of the statistical data, but allows one to make a number of guarded observations:

- The responding building officials appear to have a highly variable responsibility for basements, ranging from zero to 45,000 units with a median of 2,200 units. From some responses it is clear that the officials' responsibilities lie mainly in the inspection of new basements.
- The incidence of serious problems in all basements, whether retrofitted or not, appears to be highly variable from one municipality to another. Where numbers have been given, the number of cases per municipality ranges from zero to 250, with a

median of zero. Where percentages have been given, it ranges from zero to 50% with a median of 1%.

- If one excludes obvious cases of new construction, the number of retrofitted basements per municipality ranges from zero to 12,000 (median 150) where numbers have been given, and zero to 100% (median 30%) where percentages have been given.
- Only 16 respondents were aware of any specific problem cases in retrofitted basements. The maximum was 12 cases per municipality and the minimum was 1 to 2 cases per municipality (median of 3 cases). The total number of identified cases was 50.

Where officials knew of specific problem cases they were asked - in questions 7 to 11 - to give further details. The responses to these questions are summarized in the following Tables 5.1 and 5.2. Note that these are based on questionnaires from only 16 respondents who gave multiple responses to each question. The raw data are given in Appendix F on pages F3 and F4.

In addition to statistical information, the building officials were invited to comment on the issues of retrofitted basements and associated problems. These comments are presented in Appendix G, and it should be noted that many of the technical comments consist of unsubstantiated opinions. The most relevant comments were as follows:

- Generally, homeowners do not obtain permits for retrofit work, and if problems occur they may not always be reported to the official. The information flow is therefore poor.
- Lack of adequate soil or drainage system can cause adhesion freezing in both insulated and uninsulated basements.
- Exterior insulation has been identified as a solution to some problems.

Question #7 (15 responses from 14 respondents)		Question #8 (26 responses from 16 respondents)		Question #9 (23 responses from 16 respondents)	
RETROFIT TYPE		HOUSING TYPE		BASEMENT WALL CONSTRUCTION	
interior, full depth	73%	detached	62%	concrete block	61%
interior, part depth	27	semi-detached	23	poured concrete	30
exterior, full depth	0	row	15	rubble	9
exterior, part depth	0			solid brick	0
floor insulation	0				

Table 5.1 Percentage of responses relating to construction features of
retrofitted basements with problems

Question 10 (83 responses from 16 respondents)		Question 11 (46 responses from 16 respondents)	
DAMAGE TYPE		DAMAGE CAUSES	
major wall damage	28%	cooling of soil	20%
moisture-related	20	moisture movement	17
int. surf. deterioration	18	retrofit technique	13
retrofit system	10	water leaks	13
ext. surf. deterioration	8	cooling of wall	13
material deterioration	7	lack of maintenance	7
other	9	air leaks	2
		other	15

Table 5.2 Percentage of responses relating to damage causes
and types

- Frost-related problems may occur if insufficient heat is supplied to the soil by basement heat loss.
- Condensation can occur on the interior between the concrete wall and the damp-proofing vapour barrier (presumably where polyethylene is used for damp-proofing). Condensation can also accumulate in the insulated space and on the vapour barrier between insulation and living space.
- There is a need to study whether problems due to basement insulation can occur.

5.3 Telephone survey

The specialists were asked if they were aware of specific cases relevant to this study. The 102 responses can be broken down as follows:

- 4 answered "yes" and identified specific cases,
- 66 answered with a plain "no",
- 16 answered "no" but added comments,
- 16 felt that there might be problems but were not able to quote specific cases.

The specialists' comments reveal a consensus and a general concern about problems arising from basement retrofit, even though the majority were not able to quote specific instances. Poor soil quality, poor drainage and lack of sealing during retrofit are perceived to be major causes of moisture problems, in the form of condensation or frost accumulation behind the insulation. There is some difference of opinion about the role of the vapour barrier: some feel that it is beneficial, others feel that it is not.

Special techniques of termite-proof construction are required in affected localities. Termites can burrow through insulation materials such as beadboard and

can then travel through the spaces behind the insulation. In some cases, a retrofitted termite-prone insulation may create a new route to wood components, by-passing the masonry.

Some insulation materials, such as polyisocyanurate, have been found to deteriorate under moist conditions, with consequent loss of insulation properties.

There are several comments relating to the importance of adhesion freezing and frost heave. One specialist has noted that frost heave can occur even when footings are below the 4-foot level - an important observation that obviously deserves further consideration.

The most important comments fall into two categories. The first category has led to the identification of four well-documented problem houses. These are reviewed in section 5.4 below. The second category relates to localities in Ontario, where there appear to have been widespread incidences of foundation damage arising from combined frost heave and adhesion freezing. These incidences, and the steps that have been taken to authenticate them, are discussed under the section 5.5 below.

5.4 Specific problem houses

On completion of the Allen-Drerup-White survey, and after assessment of the information, about 50 specific cases were short-listed for further investigation. Detailed questionnaires were sent out, but the response was very poor and it soon became necessary to abandon several of the avenues of enquiry. Eventually, this phase of the study was reduced to the four specific cases described below, though it is clear that a more cooperative response would have revealed a larger number. To maintain confidentiality, the four identified cases are identified only by their city of origin.

The Ottawa House:

This house was reported by an officer of the Building Performance Section, Division of Building Research, Ottawa.

The house is 35 years old, is of wood frame construction and has a concrete block basement. The lot rises about 2m from the street, but the ground around the house is flat. The original clay soil was used as backfill. It is not known if the house is equipped with perimeter weeping tiles.

The insulation retrofit consists of full-depth rigid glass fibre insulation (RSI 1.35) applied to the interior, with the foil backing carried to the sub-floor above. The vapour barrier is caulked and sealed at all edges; the quality of the installation is high.

The first signs of damage occurred 4 months after the completion of retrofit work, during the second half of the winter period. Horizontal cracks appeared in the foundation wall at the north corner of the house, and vertical cracks appeared in the first-floor wall. The foundation cracks are 3 mm to 4 mm wide and give a noticeable air leakage when the furnace is on.

To determine the cause of the problem the soil around the basement was excavated as close to the wall as possible. The top 0.7 m was found to be hard frozen and firmly attached to the basement wall. The cause can therefore be assigned fairly confidently to a combination of frost heave and adhesion freezing, but there appears to be some conflict of opinion about the origin of this frost heave and adhesion freezing. One researcher attributes it to the fact that a water hose was left running near the foundation; another attributes it to the effect of basement insulation,

with shading, zero snow cover and frost-susceptible soil as contributory factors. The water hose theory appears to be more consistent with the facts. If this is correct, then it would be reasonable to interpret the frost heave and adhesion freezing as being artificially induced. Whatever the cause of the problem, the specialists who have direct knowledge of this house appear to regard it as an atypical case with no general relevance.

The Barrie House:

This was reported by the Chief Building Inspector of Barrie.

The house is an 80-year-old wood frame structure with a coursed rubble basement wall, finished on the inside with 100 mm of poured concrete at some subsequent date. The grade around the house was flat and there was no perimeter weeping tile. A porch was attached on one wall. The house was demolished shortly before this study and was not available for a follow-up inspection.

The house was retrofitted 7 years ago. Batt insulation (RSI 2.06) was installed on the interior of the basement wall, but not to full depth. The wall was not damp-proofed and a vapour barrier was installed on only one wall (not the wall with the attached porch).

The observed damage consisted of rot of wood joists and sill plate where the vapour barrier had been installed. The investigating official blames the problem on the vapour barrier. He notes that this is a common finding in his investigations of older houses, and that there is no evidence of moisture accumulation when there is no vapour barrier. He feels that the problem originates not from heating in winter, but from excessive moisture migration in spring, summer and fall.

The Thunder Bay House:

The damage was reported by the owner, who is a planner with the municipality.

The house is four years old, of wood frame construction with a poured concrete foundation. Original soil was used as backfill and the grade slopes away from the foundation.

The basement was insulated at the time of construction using glass fibre batt (RSI 1.41), but not to full depth. The damp-proofing on the exterior consists of plastic film. A vapour barrier was installed, but was not sealed at the bottom or around windows.

The problems consist of heavy frost build-up (up to 25 mm thick) around windows, with damage to batt and drywall. The cause appears to be a poor construction technique. Backfilling was carried out before the basement windows were installed, and soil was introduced between the damp-proofing film and the foundation wall. It is also believed that air leakage occurred around the window frames, causing freezing and accumulation of available moisture in the insulation cavity. An attempt has been made to rectify the problems by re-installing the insulation, carefully re-fitting the vapour barrier and sealing around the window frames. So far, this appears to have been successful.

The Cornwall House:

This problem was reported by the Building Inspector.

The house is 40 years old, of wood frame construction with a concrete block basement wall. The grade around the house is flat, and there is no eavestrough or weeping tile.

The retrofit was conducted 10 years ago. Full depth batt insulation (RSI 1.38) was installed on the interior, with no vapour barrier.

The suspected damage is in the form of increased water leakage through cracks in the lower part of the block wall and in the footing. The Building Inspector feels that the reduction in heat loss to the surrounding soil has caused frost heave.

Following a more detailed investigation, horizontal cracks were detected in the block wall 0.5 m below grade, suggesting that adhesion freezing might have been a contributory cause of failure. Exterior insulation has now been installed, and appears to have solved the problem. The Building Inspector commented that several cases of adhesion freezing have been encountered in the Cornwall area.

5.5 Apparent cases of frost heave and adhesion freezing

A number of apparent instances of frost heave and adhesion freezing are reported to have occurred in four municipalities in Ontario: namely Peterborough, Kingston, Sudbury and Cornwall - the last based on the comment noted above. A few specialists have identified these locations positively; other specialists appear to have based their knowledge on hearsay, and the cases they cite can probably be traced to one or another of these locations. Eakes (10) has discussed the topic and has heard of problem cases, but has not been able to obtain specific information from reluctant homeowners.

It was considered important to the aims of this study to investigate and attempt to authenticate these cases. Under the cost constraints of the Allen-Drerup-White survey it was not possible to carry the investigation through to its logical conclusion. This was rectified by the follow-up investigations described in sections 2.2 and 2.3. The following details are assembled from these sources of information.

Cases at Peterborough:

A number of foundation problems occurred in Peterborough in 1979 and were believed to have been caused by frost heave. As a result, this municipality now recommends against insulating to the footing of the basement on the interior. The Ontario Ministry of Municipal Affairs makes a similar recommendation in the booklet "Conserve Energy When You Renovate".

Enquiries through the Peterborough Buildings Branch reveal that the Branch recommends a gap of 6 to 12 inches below the insulation. This is a strictly verbal recommendation, not enforced by code. It was developed in response to an undetermined number of foundation problem cases, occurring many years ago.

Investigations conducted during the Allen-Drerup-White study, together with independent investigations by Pressnail and Tremayne, have identified only a single problem case. The foundation wall was long and built of 10-inch block. Part of the wall had been displaced inwards. Based on a detailed examination, it has been concluded that the damage was caused by hydrostatic pressure resulting mainly from a clogged foundation drain, whose effects were aggravated by poor surface run-off arrangements.

The Peterborough Buildings Branch is not aware of any frost problems arising from basement insulation. The practise of leaving a gap at the bottom of the basement insulation is still being advocated, on the grounds that there is no point in taking chances.

Cases at Sudbury and Kingston:

In December 1983 the Ontario Building Code Branch issued a note relating to adhesion freezing around insulated basements. The note was prepared in response to representations made to the Branch. Changes in the building code now require the use of non-frost-susceptible soils for backfill. The note states:

"...It was brought to the attention of the Building Code Branch, by builders, building officials and Home Warranty officials, that a phenomenon called adhesion freezing was occurring more frequently, particularly in Northern Ontario and in heavy clay areas of the province.... This problem is most prevalent in situations where basements are well insulated, preventing the conduction of heat to the outside..."

An amendment to the Ontario Building Code was issued in November 1983, requiring the use of clean granular materials for backfill. This has met with some reaction from the building industry and has recently been revised, allowing local building officials to specify the type of backfill according to local soil type and conditions.

The author of the original note was contacted as part of the Allen-Drerup-White survey, and was invited to comment. He stated that problem cases had been reported in Sudbury and Kingston. He had attempted to obtain further details through the authorities in Sudbury and Kingston, but these authorities could not confirm a single case. The CMHC Inspector in Sudbury

stated that he had offered to inspect all cases of insulation-related foundation problems, but not one contractor has approached him.

Pressnail has conducted an investigation of the problems at Sudbury and has reported a case of basement damage caused by adhesion freezing coupled with frost heave of an attached garage (11).

Cases at Cornwall:

According to the results of the Allen-Drerup-White study, a number of possible cases of frost heave damage have come to the notice of the Engineering Department of the City of Cornwall. A brief follow-up investigation has been conducted by Tremayne. The Engineering Department has commented that the problem is not extensive and only 8 to 10 cases of foundation failure have been identified. Not all of these were the result of basement insulation work.

The suspected frost heave problem tends to occur on older houses with concrete block foundations, poor concrete mix and no eavestroughing or weeping tile system. The problem has not been observed in solid foundation walls. The location is predominantly on northern walls (attributed to lack of solar gain) and close to driveways and walkways that are kept clear of snow. The symptom is cracks in the wall about 450 mm to 600 mm below grade. Frozen soil has been found close to the foundation wall and appears to be the main justification for the frost heave diagnosis.

From the limited information available it seems certain that the basement problems were caused by frost heave. However, the poor drainage arrangements must be viewed as an important factor, and perhaps a dominant one; given proper eavestroughing and weeping tile systems the problems might not have occurred. In some respects, the situation is similar to that of the Ottawa house.

Reality or illusion?

When the above cases were first encountered during the course of this study, they were believed to be genuine examples of foundation problems arising from frost heave and adhesion freezing. If this had been substantiated it would have had important consequences for basement insulation techniques. The above-mentioned investigations have shown that in many, if not all of the problem cases, mis-diagnosis has been an important component.

It is important that the scientific and building communities should recognise where they have been led by this kind of mis-diagnosis. Building practises have been changed as a consequence, and there is a prevailing misconception about the significance of frost heave and adhesion freezing, perpetrated mainly through hearsay, and traceable to cases of doubtful authenticity or no authenticity at all.

Whenever a sustained attempt has been made to cut through the hearsay and authenticate the instances of presumed frost heave and adhesion freezing, the evidence disappears into thin air or some other cause is found for the problems. This applies to the present study and has also been the experience of other researchers. Timusk, in his capacity as Chairman of the CHBA Task Force on Adhesion Freezing, has tried to obtain access to "reported cases" but has never been able to authenticate a single one. Mitalas of the National Research Council of Canada, in his response to the specialist survey, notes that he has looked for cases for 10 years but has not yet found a real case of living-space heave.

However, Mitalas also notes that he has encountered problems of step heave and garage heave. The phenomenon of garage heave has also been identified at Sudbury. These types of frost heave, associated with

unheated garages and steps, appear to be the only ones worth serious consideration.

5.6 Information from databases

During the course of the above surveys two large databases were identified as possible sources of information on basement problems. These consisted of files held by CGSB and by the New Home Warranty Program of Ontario (NHWP). An approach was made to these two agencies to determine the potential usefulness of their databases.

The NHWP file includes records of foundation failure or damage, but with little supporting information except where volunteered by the homeowner. The NHWP officials will not allow access to their files but will release some homeowners' names.

The CGSB file is computerized and consists mainly of inspectors' reports on CHIP insulation deficiencies which must be rectified by the contractor if he is to avoid de-listing. Homeowners' complaints are recorded and filed in each contractor's file, but are not numerous. Basement damage is not listed in an easily accessible way and, what is more, very few basements have been insulated under the CHIP program.

It is possible that these two databases contain a small number of relevant cases, but not enough to justify the expensive search and investigative procedures that would be required.

Scheuneman has identified three sources of information which supplement the statistical data produced by the Allen-Drerup-White survey. This chapter consists of Scheuneman's summary and conclusions relating to the findings from these sources.

The first source consists of data files from the Enersave Program for the period September 1979 to March 1981, embracing a total housing population of 129,844 units. The following table gives the percentage incidence of houses with insulated foundation walls, broken down according to house age and extent of insulation.

Extent of insulation	Age of house			Total
	pre-1945	1945-61	post-1961	
None	15.8	17.0	13.5	46.3
Some	1.5	3.7	3.9	9.1
Half	1.2	4.3	6.7	12.2
Most	1.0	3.6	7.6	12.2
All	1.2	3.4	15.7	20.3
"Most" + "All"	2.2	7.0	23.3	32.5

Table 6.1 Incidence of insulated foundations, from
Enersave Data

The second source consists of an evaluation of the Canadian Home Insulation Program (CHIP) conducted by EMR and reported in November 1983 (Report No. PE 50/1983). The following table shows the percentage of houses with insulated basements, broken down into basements insulated under the CHIP Program and those insulated without CHIP assistance.

Respondent	Sample size	Percentage
CHIP	840	34
non-CHIP	2,810	28
Weighted total	3,650	29

Table 6.2 Insulated basement incidence from
CHIP evaluation

The similarity of the percentages for the CHIP and non-CHIP houses is interesting, and probably arises from the fact that insulated basements constitute a useful living space. Energy conservation is a natural piggy-back which does not need CHIP support as a primary motivation. The termination of the CHIP program should therefore have little influence on the amount of basement insulation work.

The third source consists of a survey conducted by Scanada (Thermal Fitness of Canada's Housing Stock: a Thermography/Photography Survey. Scanada Consultants Limited, September 1982). The following table 6.3 gives the percentage of houses with insulated foundation walls, for various cities across Canada.

It is interesting to note the large regional variation displayed in the table. The Scanada report concludes that 30% to 40% of basements in central and eastern Canada are insulated, but only 5% to 10% of those in western Canada. This suggests a possible further study directed at climatic, technical and motivational (cost) reasons. Overall, about 22% to 33% of Canada's basements appear to be insulated. These figures are based purely on thermographic scans taken from outside the houses, which give information only on the sections of basement wall visible above grade. Where there is above-grade insulation it is reasonable, in the majority of cases, to assume that this extends to most of the basement wall.

City	Sample size	Age of house					Weighted Total
		pre-1945	1945-50	1951-60	1961-75	1975-82	
St John's	1104	3	1	10	62	79	41
Fred./Monc.	379	2	0	0	13	65	18
Montreal	336	50	31	2	0	0	9
Hull	104	0	4	0	61	100	44
Toronto	1124	3	10	13	51	99	29
Winnipeg	2021	2	7	15	7	92	14
Calgary	538	0	0	0	1	0	1
Edmonton	673	0	0	0	0	0	0
Victoria	40	0	0	38	0	0	38
Total	6319						

Table 6.3 Percentage of houses with foundation insulation: Scanada Study

These three studies give remarkably similar results, indicating that about 30% (or about 2 million units) of the Canadian low-rise housing stock have basement insulation.



7.1 The incidence of problem cases

Taking the responses of the 148 building officials at face value, they would appear to have a collective responsibility for about 500,000 housing units, possibly subject to a factor of two in either direction. This is statistically large enough to give some idea of the incidence of the type of problem being studied.

Unfortunately, the estimates of the numbers of retrofitted basements, and the proportion of these with problems, have such a large spread that they cannot be considered entirely consistent or reliable. In a housing stock of 500,000 the number of retrofitted basements could be anywhere in the range of 20,000 to 200,000 depending on how the responses are interpreted.

The survey has revealed only 50 problem cases, suggesting that, in retrofitted basements, the incidence of problems will be about 1 in 400 at worst and might be as low as 1 in 4,000. There are several reasons for distrusting these figures. First, if it had been possible to assess the 50 problem cases, it is likely that some could have been rejected for one reason or another. Secondly, a problem must display obvious symptoms before the homeowner becomes aware of it, and it is therefore likely that a number of undetected problems exist. Thirdly, it appears that homeowners and contractors have a variety of reasons for concealing problem cases from building officials. As a result, only a fraction of the actual problem cases are brought to the attention of building officials, and this fraction cannot be estimated. Fourthly, it is clear from the responses of building officials that they are aware of more problem cases than are documented, though some of these cases may not be relevant.

Though the survey does not give a reliable indication of the incidence of problem cases, it does indicate that problems with retrofitted basements are not as commonplace as some people believe.

The statistical information provided by Scheuneman (see the previous chapter) adds strength to this point, showing that there are probably as many as 2 million insulated basements in Canada. Given this figure of 2 million units, and given the generally-held views about problems induced by retrofit, one would have expected to see a large number of problem cases - of the order of thousands - coming out of the Allen-Drerup-White survey. The experience has been quite the opposite: it has been difficult to find problem cases. Of the few cases that have been identified, only a small fraction can be positively attributed to the effects of basement insulation. In the words of Timusk: "...the cases are not out there."

The implications are obvious: the general perceptions about retrofit-induced foundation failure are ill-founded and inaccurate. Some of this is undoubtedly due to excessive reliance on hearsay or technical gossip. At one point during the study it appeared that there were four houses in Ottawa with similar symptoms of retrofit-induced foundation failure. On further investigation it was found that these were one and the same house, expanded to four by the different descriptions of different specialists.

On the basis of all the information presented so far in this report, Scheuneman notes that "...the incidence of problems due to insulation is very low and at least ten times less frequent than other basement/foundation problems requiring remedial action." There is an emerging belief, as yet unsupported by firm facts, that the effects of basement insulation may be potentially beneficial rather than potentially harmful.

7.2 Specific problems

First, it should be noted that the survey has embraced a housing sample of about 500,000 units (estimated above), constituting only about 6% of the total national housing stock. Therefore, the survey has probably identified only a small fraction of the problem cases (note that this does not negate the fact that the incidence is low anyway).

Secondly, and with reference to the problem types reviewed in Chapter 3, it seems that many of these are occurring or are suspected to occur in practise. Unfortunately, few of the problem cases have been investigated or documented in sufficient detail. The remainder, though possibly relevant, have had to be treated as unauthenticated cases within the terms of reference of this study. Three causative processes are of particular interest, and are discussed under separate headings in the following text.

Frost heave and adhesion freezing:

The phenomena of frost heave and adhesion freezing in soils are well established, and the forces arising from these processes are known to be potentially large enough to cause damage to foundations (2,3,7). In the past, and right up to the present, there have been a number of cases of foundation failure that have not been fully investigated and, rightly or wrongly, have been attributed to frost heave and adhesion freezing effects. Thus, there has been a generally-understood process of foundation failure, and a number of actual cases of failure that superficially appear to be explainable by this process. From the vantage point of this study, it can be said that this is a case of two wrong things supporting each other.

This study, and the work of Pressnail (11), have fortuitously come together at the same time to give a new perspective on the problem.

The study has found no convincing evidence of foundation failure as a result of frost heave and adhesion freezing, except in one case where severely atypical conditions were the dominant factor. Other researchers, who have been monitoring basement failures for several years, have likewise found no convincing evidence. On its own, this lack of evidence is not proof of anything, particularly if it seems to conflict with the generally-understood processes. Thus, even with the findings of this study, it would be prudent to entertain some residual doubts.

The work of Pressnail (11) goes some way towards removing these doubts, by examining the processes of frost heave and adhesion freezing in greater detail and showing that they are substantially modified by the conditions around a heated basement - to the point where adhesion freezing is unlikely even if the basement is insulated. This work has not yet been subjected to the scrutiny of the scientific community at large, and therefore an element of caution is desirable at this stage. The best that can be said at the present time is that there are no convincing cases and there is a new hypothesis that is consistent with this finding.

Unheated garages and attachments such as steps are an exception, and may be subject to frost heave that can be transmitted to the foundation of the living space. The incidence is not high; a few cases have been authenticated and are explainable on the basis of Pressnail's work (11).

Moisture damage:

The Barrie House is a clear example of moisture damage, though it is difficult to say if this was an existing problem or one induced by retrofit. On one hand, the poured concrete layer on the interior may have been an attempt to remedy an existing problem of joist deterioration at the top of the rubble wall. Also, the lack of moisture damage at the opposite end of the joists may have been due to the effect of the attached porch.

On the other hand, the observed moisture problem is consistent with the physics of moisture movement and with the effect of the vapour barrier on this movement. Rubble walls, with their high proportion of mortar, are considered to be more vulnerable to this type of damage. Also, the Building Inspector's comments on similar occurrences are fairly forceful and cannot be entirely discounted.

On balance, the Barrie house appears to be a genuine case of retrofit-induced moisture damage. This type of moisture damage - at the interface of the foundation and the wood frame - is considered by specialists to be a major source of concern in retrofit technology, partly because of its harmful effects on structural integrity. The Barrie house tends to support this concern.

Specialists are also concerned about the possibly high incidence of this type of damage. The survey has not proved that a high incidence exists, but neither has it disproved it. This type of problem is not obvious to the homeowner, and may not make its presence known until it has progressed to the point of major structural failure. A large proportion of basement retrofit work has not been in place long enough for this to happen. The comments of the Barrie Building Inspector indicate that the problem may be more extensive than has been revealed in the survey.

In recognition of the importance of this type of moisture damage, a detailed discussion by Timusk is included in Chapter 8.

Poor construction technique:

The Thunder Bay House is an example of poor construction technique. The problem was due to a departure from sound constructional procedures, rather than to any inherent defects in the existing codes and standards. When unqualified persons attempt retrofit they have an obligation to familiarise themselves with sound building practise. The right kind of information is readily available in at least one good publication (6).

7.3 The need for further research

Two types of relevant foundation problems have emerged from the study: moisture problems at the top of foundation walls, and problems due to the transmission of frost heave effects from unheated garages. Further research is required on each problem type to define the situations under which they can occur and to develop and evaluate remedial measures and suitable retrofit techniques.

From this study it has been concluded that, in typical and non-extreme situations, frost heave and adhesion freezing have no direct effect on foundations around heated living spaces, whether insulated or not. This conclusion rests partly on the lack of authenticated cases and partly on a new interpretation of the physical processes, as advanced by Pressnail (11). Although these new ideas seem reasonable, they have yet to be validated conclusively. Until this is done, all the conclusions about frost heave and adhesion freezing will have an element of uncertainty. The continuation of

Pressnail's work should be encouraged, with emphasis on the validation of his new model.

7.4 Technology transfer

The results of this survey rest primarily on the responses of 148 municipal building officials, to whom grateful acknowledgement is made. Among these officials there is a considerable variation of expertise: some are well informed on the technical issues while others are not. Many were looking for advice, guidance or assistance. Basements are a major source of housing problems, and the causes of these problems are not easily understood. Basement retrofit introduces another dimension, adding further confusion to the overall picture. A good, simple, layman's guide to basement problems and retrofit technology would be invaluable to these building officials.

Such a document would also prove invaluable to homeowners. By presenting the main elements of good construction practise it would avert some of the problems that are now arising as a consequence of poor construction technique.

In the immediate future, the main thrust of the technology transfer should be to re-educate both the technical and building communities on the subject of frost heave, adhesion freezing and their potential for causing foundation problems. It would appear that many inspectors and other specialists have adopted frost heave and adhesion freezing as a convenient scapegoat for certain types of foundation problems. The required message is clear and simple: with the exception of effects transmitted from attached unheated structures such as garages, frost heave and adhesion freezing effects do not occur with sufficient frequency to warrant concern or to justify significant changes in building practise.

This chapter has been included to allow one of the co-authors (Timusk), to express concerns about the practise of insulating joist spaces when the joist ends are embedded in solid masonry walls. While such constructions have performed well for a considerable length of time without the presence of thermal insulation, there is a possibility that, in summer conditions, the relative humidity in the insulated space around the joist ends could become high enough to induce rot of the ends. These concerns have been expressed previously by Timusk (6) and are amplified here.

(Editorial Note: The material in this chapter is partly hypothetical and partly based on an extrapolation of experiences from other (similar) building configurations. No direct evidence of the proposed type of moisture problem in residential basements has been encountered during the course of this study. Nevertheless, this chapter has been included on the grounds that it gives a well-reasoned warning that should not be ignored.)

8.1 Introduction

In order to reduce heat losses from heated buildings it is necessary to impede heat flow. This is accomplished through the introduction of a layer of thermal insulation which, in the case of thermal retrofitting, will usually have to be applied to either the interior or the exterior surface of the existing wall. The direct consequence of the added thermal insulation is a change in the temperature of the original wall. If the insulation is placed on the exterior surface of the wall, the mean wall temperature during the heating season will be raised while during the summer it will be lowered somewhat with respect to pre-insulation conditions. If the insulation is placed on the interior side of the wall, the converse will be true.

A change in wall temperature will, in turn, lead to a change in the interchange of moisture between the wall assembly and its surroundings. Such moisture movement and associated moisture content change can, depending on when the insulation is placed, lead to an increase or a decrease in the rate of decay of materials making up the structure. In particular, wood-based products are known to decay once favourable moisture and temperature conditions are established. This is feared to be the case when insulation applied to interior faces of solid masonry basement walls is extended to the underside of floor sheathing, thereby also covering the space between floor joists which are, in turn, fire-cut and framed into the solid masonry wall.

An attempt will be made in this chapter to provide various arguments upon which the fear is founded. The topic will be developed in more or less discrete, self contained elements. Each such element is intended to provide an argument which in itself should suffice to make the case against such insulation practise.

8.2 Lessons from the Ming Master Builders

Now that the word science has been tagged onto building, one has to be very careful not to throw away the most reliable method of sorting bad building practise from good. The master builder of by-gone days was a keen observer with a healthy respect for tradition. Time-honoured building practises must always be kept as models. If building science, the way we understand it, is in conflict with a successful solution, then it is not the successful solution which is deficient, nor science, but rather our understanding of science.

The Ming Master Builders (12) had apparently realized that beam ends terminating in blind pockets in masonry walls were in danger of premature rotting.

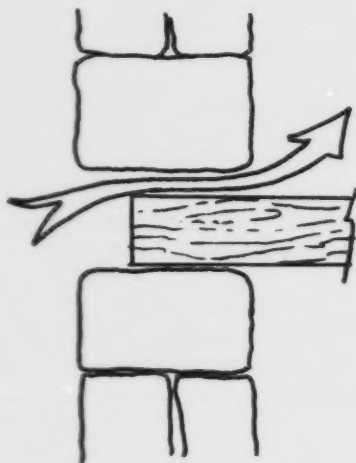


Figure 8.1 Beam end detail from K'ang-Ling tomb. 1521.

To avoid a build-up of moisture at the beam ends, the holes were extended through the heavy masonry wall to provide ventilation (figure 8.1).

There must have been a good reason for providing ventilation for the beam ends. The similarity between the wall of the unheated tomb building and internally insulated masonry basement wall is striking. But the basement wall condition is more severe in that all drying toward the interior is cut off by the necessary room-side vapour barrier. Further, the availability of the moisture is greater for the basement wall which is founded in damp soil and where frequent wetting due to lawn sprinkling is common.

8.3 Observation by H. Sillaste, Architect

Severe spalling of brick masonry in an habited coach house prompted the removal of insulation from the interior surface of the solid masonry wall. This work was carried out during the middle of the summer and when the wall covering and EPS insulation was removed it was found that a layer of polyethylene had been placed between the masonry wall and the thermal insulation (figure 8.2). There was so much water on the outer face of the polyethylene that "when the polyethylene was pushed against the wall, water was running away in all directions from the depressed area".

This condition is not unlike that of the internally insulated basement.

The owner of the property also indicated that the west-facing coach house wall was occasionally soaked during lawn watering.

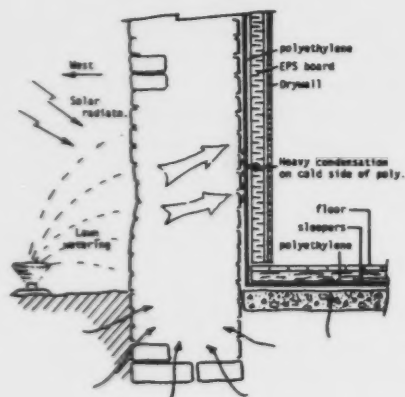


Figure 8.2 Situation reported by Sillaste.

8.4 Moisture Problems at Concrete Floors

Nilsson's 1976 University of Lund publication (13) describes a number of cases where wood based and other organic materials in contact with concrete slabs on grade have experienced difficulties when the floor surface was covered with vapour impermeable materials. Here the conditions are less severe than in the case of the basement wall in that the heat flux is always away from the interior. Nevertheless, problems have occurred in sufficient number to warrant recommending measures to reduce the relative humidity in the concrete to less than 80%.

8.5 Further Observations

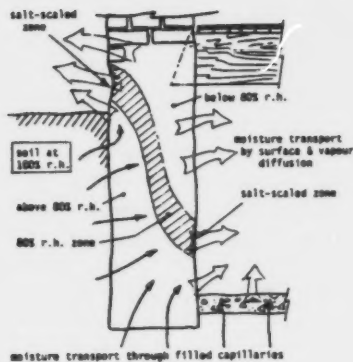


Figure 8.3 Moisture movement in an uninsulated solid masonry wall.

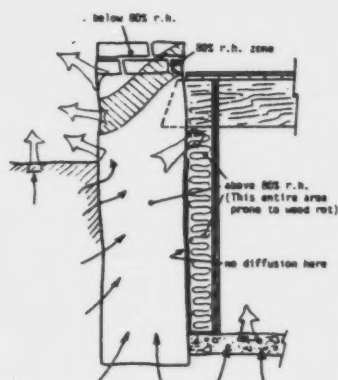
Figure 8.3 depicts conditions before a basement wall is insulated. The entry of water by capillary action (indicated by small arrows) takes place through all surfaces in contact with the soil. To present a simple picture, capillarity is shown ending in the hatched zone. Absorption isotherms for clay brick suggest, however, that around 80% relative humidity the capillaries in clay brick become emptied. This would suggest that, from this zone and onwards, water moves through the pores by surface and vapour diffusion. (Surface diffusion would still fall into the capillary diffusion category.)

Beyond the hatched zone vapour diffusion is indicated by large arrows. Here relative humidity is too low to cause decay of wood. The transition zone between the capillary and vapour diffusion zones is reasonably clearly marked by surface damage to building walls where salts are left behind in pores, as drying is through evaporation within the pores.

This picture depicts the separation of the capillary diffusion zone from the joist area. The joist area

remains below 80% r.h. because capillary water supply to the wall cannot keep up with the rate of the water loss to the exterior and interior air. As a consequence, moisture in the wood is kept below the level where rot could occur.

Now, if we insulate internally and seal off the entire inside wall face with a vapour barrier, only the exposed-to-the-exterior part of the wall is available to dissipate moisture. This is during the winter or heating season, when some moisture could also diffuse into the occupied space above.



During the summer, on the other hand, the exterior wall now provides an additional supply of moisture (As it did for the architect H. Sillaste). Soil moisture, rain water and lawn sprinkling water will be forced into the basement to condense on the polyethylene (figure 8.4). The entire wall below the 80% r.h. zone, including the insulated space and the joist ends, is at a moisture level where wood rot could occur.

To obtain a rough estimate of the magnitude of the wetting potential in winter, we can assume conditions in the cavity of 100% r.h. at 10°C (optimistically high) and an outside temperature of -5°C. Under these conditions the vapour pressure gradient, constituting a driving force out of the cavity, would be about 950 Pa at best.

Figure 8.4 Moisture conditions in an internally insulated masonry wall in contact with the soil.

For summer conditions we assume an outside wall temperature of 35°C, allowing for Sol-air effect. At saturation this would yield a vapour pressure of 5624 Pa. Assuming a basement temperature of 20°C and 100% r.h. in the insulated space, this gives a net vapour pressure difference of 3287 Pa which serves as a driving force into the cavity. This is more than three times higher than the opposite effect in the heating season. Therefore, even if we discount the experiences of the Ming builders, Sillaste and Nilsson, we have additional arguments against internally insulating the space between joists framed into solid masonry walls.

It would be valuable to conduct an experimental verification of these situations. The careful measurement of moisture dynamics for such walls would be of considerable interest and such work would have broader implications in terms of the performance of existing as well as new buildings.

Finally, a strong word of caution must be directed at those who would attempt to minimize the risk of wood decay by treating the joist ends with preservative. This might be possible by injecting preservative into the exposed part of the joist in the hope that it would diffuse into the blind end of the joist, but such work is not practical when considering commercial retrofitting. Also, certain wood preservatives can present health hazards and should be used only by qualified trades persons.

During the course of this study concerns have been expressed that, when only a part of the basement wall is insulated, the temperature differences between the insulated and uninsulated wall may establish thermal stresses high enough to cause mechanical failure. This chapter, consisting of an appraisal by Timusk, is a response to these concerns.

9.1 Appraisal of the problem

If a masonry building wall hardens at the same temperature as it is exposed to throughout its life, no thermal strains will result. In our climate the outdoor temperature varies between extremes, taking into account air temperatures and superimposed solar radiation effects. Hutcheon (14) suggests a temperature range between -33°C and $+66^{\circ}\text{C}$, a total temperature difference of some 98°C (figure 9.1).

The resulting thermal strain will be somewhat smaller in that the mortar in the wall will usually have solidified at some intermediate temperature. In figure 9.1, construction or zero-strain temperatures of -7°C , 7°C and 32°C are suggested for walls built during the winter, the shoulder months and summer respectively. This would then mean that a winter-built wall might experience a temperature drop of 26°C while the extreme temperature rise would be 72°C . If, on the other hand, one deals with a summer-built wall, the temperature drop would now become about 65°C while the extreme temperature rise is reduced to about 33°C .

Temperature change per se is not a problem; it is temperature differences which lead to stresses. When the stresses exceed the ultimate strength, failure will result.

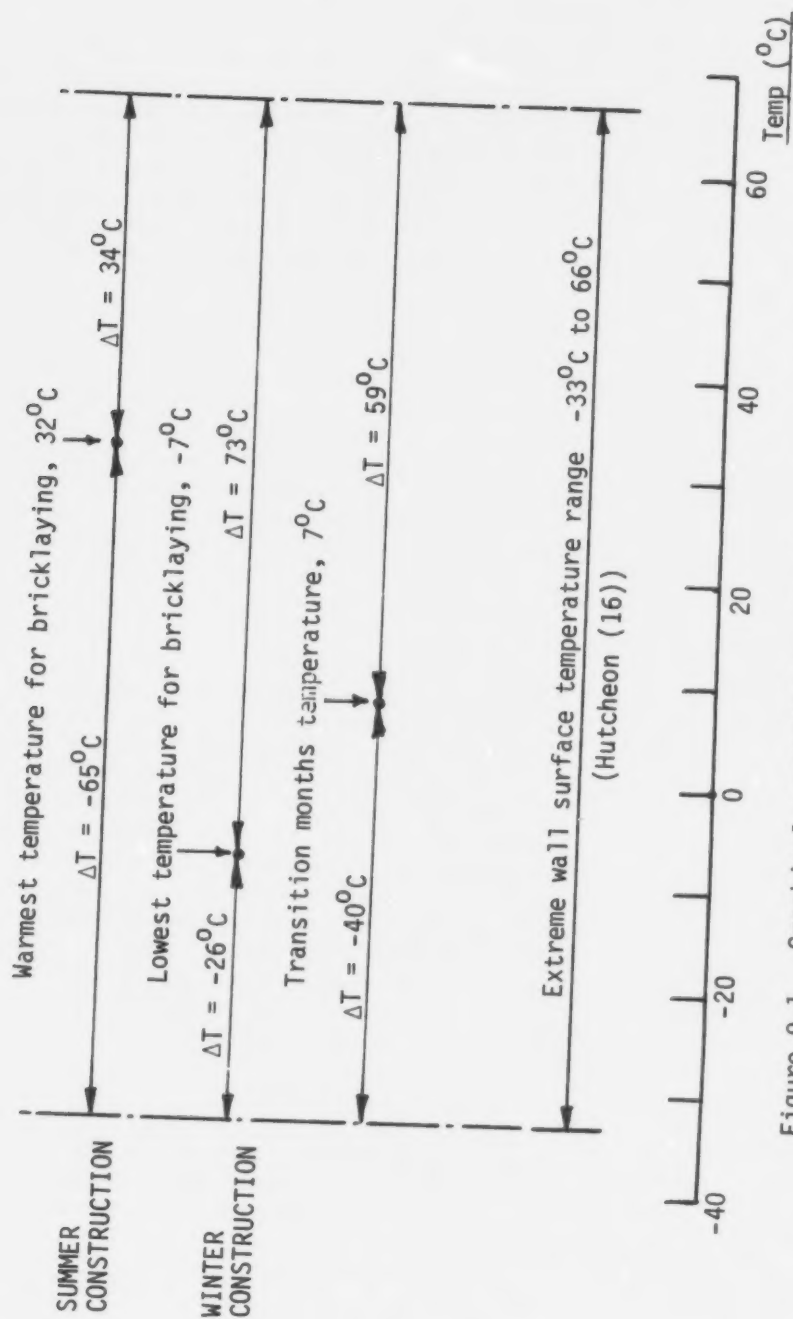


Figure 9.1 Graphical presentation of wall temperature ranges

In the case of masonry walls failure will result if the tensile stress exceeds the tensile strength of the wall. Usually, failure is hardly perceptible in that stress is relieved by the formation of micro cracks in the mortar. Such cracks will tend to heal over a period of time. Tensile and compressive stress are also relieved by stress relaxation, that is, under sustained load creep strain in the mortar will relieve extreme stress.

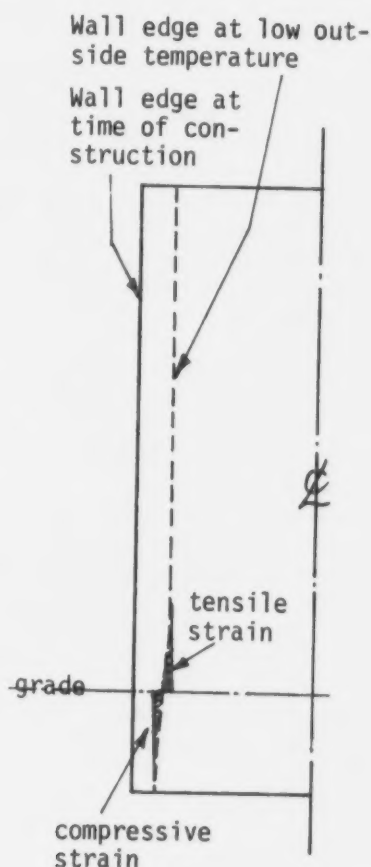


Fig. 9.2 Idealised strain distribution in a summer-built wall cooled to winter temperatures

Were one to assume linear stress-strain relationships, one could replace the temperature changes in figure 9.1 with either strain or stress. For example, were the summer-built wall to experience -33°C during the first winter, corresponding to a temperature swing of 65°C , it would contract by some constant times 65 units. However, the foundation would not experience anywhere near the same temperature swing because of the moderating effect of the surrounding soil.

Figure 9.2 shows the masonry wall continuous with the basement wall. During the winter the above grade wall would experience tensile stress, the foundation wall compressive stress.

Once the weather warms up, the wall would expand again. Zero stress would now occur at a lower temperature as part of the strain is not recoverable. All walls would, regardless of construction temperature, tend to approach some average condition.

The significant observation in this context is that uninsulated masonry walls rarely experience visible thermal cracking, in spite of the large difference between the soil temperature range at ground level (some 22°C) and the above-grade wall temperature range (some 98°C). To a large extent this must be due to the ability of the wall to accommodate extreme tensile strain through creep and micro-cracking. Once the wall has survived the first cold winter or

hot summer, subsequent stresses due to similar temperature swings will be smaller.

If the basement wall is thermally insulated at some later date, the new temperature change will be imposed on an already stress-relieved wall. New cracking is therefore not expected. Nor has any been reported as a result of thermal retrofitting.

While one could calculate the free tensile or compressive strains due to a given assumed temperature change, it would be virtually impossible to calculate the resulting stresses due to the complicating effects of micro-cracking and creep-caused stress relief. The calculations, in the writer's opinion, would not provide more insight than the above arguments.

Accepting that thermal insulation may create greater differential movements and stresses than in the case of uninsulated basements, then new basements would be more likely to experience difficulties in that they would lack the previous stress-relieving experience of the retrofit basement.

In conclusion, it can be stated that thermal retrofitting of masonry basement walls is unlikely to lead to significant cracking.

A survey has been conducted on problems occurring in foundations after they have been retrofitted. Financial and scheduling constraints prevented the use of exhaustive survey techniques. The findings are therefore based on the responses of 148 municipal building officials and on telephone interviews with 102 specialists in this field. Supplementary studies have also been conducted, dealing with the statistics of retrofitted basements, investigations of some cases of foundation failure, and interpretation of the study findings in the light of the current state of the art. The main conclusions are as follows:

There is an estimated population of about 2 million retrofitted basements in Canada. The survey was not designed to deal with this entire population, but has embraced a statistically large proportion. If retrofit-induced foundation problems were occurring with the frequency that some people believe, then the survey would have produced compelling evidence. But only a small number of cases - at most 50 - have been identified. There are various reasons for distrusting the accuracy of this figure, but even when these are taken into account it is clear that basement retrofit has little risk of causing foundation problems. This finding is supported by the polled responses of specialists, who have been able to identify only a few authenticated cases.

Accepting the limitations on the accuracy of the survey results, there is nevertheless a fairly strong indication that basement retrofit causes fewer problems than are encountered in conventional basement construction practise. In general, basement retrofit practises tend to be more beneficial than harmful.

The few authenticated cases of retrofit-induced foundation problems can be divided into three categories, arising from:

- combinations of frost heave and adhesion freezing,
- moisture accumulation at the top of the foundation wall,
- sub-standard constructional practise, which is not strictly relevant to this study.

Frost heave and adhesion freezing have not been found to cause problems in heated and uninsulated foundations, and there is no evidence that such problems will arise after the foundation has been insulated. Exceptions have been found to occur where there is a structurally-continuous, unheated adjacent structure such as a garage. In such cases, frost heave under the adjacent structure may indirectly cause damage to the foundation around the living space.

Several cases of apparent frost heave and adhesion freezing damage to insulated and heated basement walls have been reported, but only one case has been authenticated. The observed damage has been attributed to frost heave and adhesion freezing, but the conditions were somewhat extreme and unusual, making this a special and rather extreme case. Two scientists, who have independently monitored apparent cases of frost heave and adhesion freezing for several years, report that they have not yet found a single authentic case, with the exception of indirect effects from unheated garages.

This conclusion about the negligible effects of frost heave and adhesion freezing goes contrary to prevailing opinion, and cannot be justified solely on the basis of a lack of authenticated cases. The missing component has been supplied by recent research at the University of Toronto: a new model of frost heave and adhesion freezing has been developed, and the predictions of this model are consistent with the observed lack of cases.

The survey has revealed only one authentic case of moisture problems at the top of the foundation wall, arising as a result of retrofit. The case was consistent with the known processes of moisture move-

ment when applied to specific structural and retrofit configurations. Apart from this substantiated case there were several others that could not be substantiated, and there are suspicions that many more will appear in future. This type of problem is difficult to identify at the present time since the signs may not be visible until the problem has advanced to a serious stage, and this may take several years. Accordingly, the survey should be regarded as inconclusive on this point and it would be appropriate to keep a watchful eye on this type of problem in the future. An appraisal, included as part of the report, draws particular attention to cases where joist ends are embedded in solid masonry (eg. fire-cut joists).

When a basement is partly insulated, an appreciable temperature difference will exist between the insulated and uninsulated parts of the wall. Some specialists fear that this will cause wall deterioration through thermal stress. This mode of failure was not included in the survey of basement problems. An appraisal, included as part of the report, argues that partial insulation is unlikely to cause significant cracking.

The level of technical understanding encountered during the survey has not been uniformly good, and suggests a need for improved technology transfer. There is a widespread perception about frost heave and adhesion freezing which, in the light of this study and the parallel work at the University of Toronto, needs to be re-appraised.

Finally, and returning to the original purpose of this study, it is concluded that the incidence of retrofit-induced foundation problems is too low to constitute any serious obstacle to future EMR strategies regarding basement retrofit. Proven technologies can now be taken to the technology transfer stage, but it would be wise to include a fairly strong caution about potential moisture problems at the interface of wood frame and foundation.

A broad-ranging program of research, development and evaluation is recommended, consisting of the following components:

- Fundamental studies are required on the phenomena of frost heave and adhesion freezing, with two objectives: to validate Pressnail's new model and to define the problems and solutions associated with frost heave of unheated garages. A combination of controlled site research and laboratory studies may be desirable.
- A more sustained attempt should be made to identify and assess existing cases of moisture damage at the tops of foundation walls. Remedial measures should be applied and evaluated, and good retrofit practises should be established.
- To further BETT's objectives - of communicating proven technology to the end user - it would be useful to monitor and evaluate a range of basement retrofit installations over a period of at least two years, taking into account other variables such as soil type, moisture conditions and regional factors.
- To improve the understanding of basement failure processes to assist in avoiding future problems, it would be instructive to select a small number of real-life basement configurations and drive them to failure under controlled and carefully monitored conditions.

An "information flow" arrangement should be set up with building officials, to ensure that problem cases are brought to the notice of the technical community. This could usefully incorporate a "hot line" through which the officials could seek advice and guidance. (It is understood that the Canadian Home Builders Association is now developing something along this line.)

A strong technology transfer initiative is required in this area. Builders and contractors need to be acquainted with sound and proven practises. Building officials need education on failure mechanisms in foundations, and they also need guidance on appropriate remedial techniques. Do-it-yourself homeowners need to be steered away from poor constructional techniques. The average homeowner should be given information on how to identify foundation problems before they develop into major structural failure.

Allen-Drerup-White Ltd. wishes to acknowledge the assistance of Eneraction Ltd., of Regina, Saskatchewan, on the parts of the survey conducted in western Canada. The Starr Group, of Toronto, Ontario, assisted in the questionnaire mailing and survey response collection. The contributions of these two companies were essential to the survey, and their cooperation is greatly appreciated.

This survey could not have been conducted without the assistance of many specialists and building officials across Canada, and some in the U.S.A. They are too many to list by name, but their assistance is gratefully acknowledged.

The authors would like to thank the "Fine Home Building Magazine" (USA) and the "SOL" magazine of the Solar Energy Society of Canada, for publishing the letter given in Appendix D. Thanks also go to Mr. Harris Mitchell of the "Toronto Star" for his useful comments.

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APPENDIX A
DETAILS OF SPECIALISTS CONSULTED

Government and National Organizations

Energy, Mines and Resources (Energy Conservation Division) Retrofit Programs Section CREO Office "Heatline"	Jack Smith J. Klassen Lawrence Haberman Philip Jago
National Research Council (Division of Bldg. Research, Ottawa) (Building Research, Saskatoon) (Materials Section, Ottawa) (Halifax)	Bill Williamson Gint Mitilas Ken Burn Harold Orr Bob Dumont R. Ramachandran Don Tibbetts
Canada Mortgage and Housing Corporation	Jim White Phil Deacon Al Houston J. Rousseau B. MacIntyre J. Moorehead Mr. Besskler Larry O'Toole Mme. Bureau
CMHC Regional Office (Saskatoon) (Inspector and Rehabilitation Instructor)	Everett Dunham
CMHC Regional Office (Prince George)	John Allen
Canadian Building Officials' Association	Gerry Alexander
Alberta Housing and Public Works (Research and Development)	Bob Sloat
Alberta Ministry of Energy and Natural Resources (Energy Conservation Branch)	Goldie Edworthy
Alberta Agricultural Home Plans Branch	Don Warton
Saskatchewan Dept. of Agriculture (Family Farm Improvement Branch)	Don Gaylen
Conservation and Renewable Energy, Manitoba	Bill Macdonald (Director)
Regina Energy Conservation Information Centre	Jon Van der Raadt
British Columbia Ministry of Energy, Mines & Petroleum Resources (Conservation and Renewable Energy Branch)	Bill Swartz
Saskatoon Energy Conservation Information Centre	Terry Harley

TELEPHONE CONTACTS

A.2

Manitoba Dept. of Energy and Mines	Grant McVicker
Manitoba Housing and Renewal	Gay Burns Mr. Hacking
British Columbia Home Warranty	Ralph Moore
Dawson Creek Energy Information Centre (B.C.)	John Royer
Nanaimo Energy Information Centre (B.C.)	Tony Wong Brian Meheffy
Victoria Energy Information Centre (B.C.)	Peggy Carswell Joan Allen S. Wardling
Ontario Ministry of Energy	Malcolm Landers John B. Quinn
Ontario Ministry of Municipal Affairs & Housing (Housing Renovation & Conserv. Unit) (Co-ordinator, Residential Renovation) (Technical Services Division, Research and Development) (Building Code Branch)	Betty Minnes Frank Burcher A. Zdanowicz G. Feher T. Macdonald Harry Sproule Dave Pressen
Quebec Ministry of Energy and Resources	Daniele Malette J. Levielle
Housing and Urban Development Association of Canada (HUDAC)	Henry tenDen L. Nakatsui
HUDAC New Home Warranty Program:	
Representatives:	
Alberta	Larry Kelly
Saskatchewan	Neil McCulloch
Manitoba	Les Oliver
Ontario	E. Locke
Quebec	Bruno Nantel
Atlantic Provinces (Halifax)	D. Verge
Ontario New Home Warranty Program	Jack Hussman
HUDAC TRC Basement Committee	John Timusk
CGSB - Insulator's Manual	Collette Malouin Dwight Eastman

TELEPHONE CONTACTS

A.3

CHIP Performance

Canadian Building Officials Association

U.S. Army Corp. of Engineers
(Cold Regions Research and Engineering
Labs)

Bruce Gough

Gerry Alexander

Ken Childs

Universities

University of Saskatoon
(Mechanical Engineering Dept.)

University of Toronto
(Centre for Building Science)

University of Alberta

University of Waterloo
(Building Energy Group)

University of Minnesota

Oklahoma State University

Massachusetts Institute of Technology
(M.I.T.)

Bob Besant
Tom Hamlin

John Timusk

Mack Ackinnen

Eric Burnett

J.W. Ramsley

Lester Boyer

T.P. Bligh

Insulation Manufacturers

Dow Chemical (Construction Materials)

BASF (Engineering and Construction
Application Services, Montreal)

Fiberglas Canada (Toronto)
(Sarnia)

Owens Corning Fiberglas (U.S.A.)

Guy Titley

Stan Bober

Bob Sinclair
Keith Batsford
Mr. DeWil

Paul Shipp

Utilities

Ontario Hydro - REAP Program, Central Region	Vivian Whitehead Ian Grey
B.C. Hydro (Energy Conservation and Technical Div.)	Trevor Jones James Hillhead
Manitoba Hydro (Conservation Section)	Lawrence Baraniuk (Head)
North West Utilities Ltd., Alberta	Ron Gibbon
Toronto Hydro	Cliff Poyton
North York Hydro	Dan Wickiam

Contractors/Builders - Houses

Terry Mills (Renovator's Council)	
Solar Applications and Research Ltd.	Chris Mattock
NRG Industries (Enercorp)	Mr. Unrau
Marco Cardili, Contractor (Montreal - Westmount)	

Concrete and Masonry Contractors

Canadian Masonry Industry	Garth Miller
Clay Brick Association of Canada	

Other

Unies Ltd. (Winnipeg)	Gary Proskiw
EIC Consulting (Vancouver)	Don Shere
Doug Overholt - Vaughan City Inspector	
"Mr. Chips" (also author of "Insulation Aftermath")	Jon Eakes
Toronto Star	Harris Mitchell
Renewable Energy in Canada	Bob Argue Brian Marshall

APPENDIX B
SHORT QUESTIONNAIRE

SASKATCHEWAN RESEARCH COUNCIL SURVEY

Regarding Post Retrofit Damage of Insulated Masonry Basements

The Home Energy Program (HEP) of the Federal Department of Energy Mines and Resources will be promoting a wider range of insulation retrofit options for the home owner, including basement retrofits. In preparation for this, a survey is being conducted to establish if any problems have occurred as a result of the insulation of masonry basements.

It has been predicted that insulating the foundation wall may significantly increase the risk of failure of the basement wall. Some predicted problems include the following:

1. Frost heave damage to the foundation wall due to reduction of heat loss to soil.
2. Increased above-grade freeze thaw damage to the foundation wall. This can occur if interior insulation is applied, thus rendering the wall colder in winter.
3. Changes in temperature profiles and vapour transmission paths by insulating may cause increased damage to the interior or exterior surfaces or promote rot of supports of structural wood members.

While such predicted effects could have serious consequences including structural failure of various components, there exists very little substantiated information regarding increased problems as a result of insulation of basements.

The purpose of this survey is to establish the existence of such problems in the field and the approximate frequency with which these problems may occur. Your help in answering this questionnaire will be invaluable for setting retrofit guidelines, for training installers and for establishing standards for installation.

Even if you have not encountered any case of damage to basements it is important that the first section of the questionnaire be completed and returned to us as this will give us an overview of how severe these kinds of problems are.

Please be assured that all individual responses to the questionnaire will remain strictly confidential.

-1-

This questionnaire should be completed by the person within your municipality who is responsible for building inspections and related work.

SECTION A: General Information

1. What is your position in the municipality?

- ☐ Building official
☐ Engineer
☐ Inspector
☐ Municipal Clerk
☐ Other (specify) _____

2. In case it becomes necessary to contact you for further information, or to help us clarify your answers, could you please provide the following information:

Name	Phone Number
Mailing Address	Postal Code

SECTION B: Basement Information

NOTE: This questionnaire applies only to FULL-DEPTH basements with footings below the frost line. This eliminates crawl spaces, slabs-on-grade, etc.. The foundation wall is to be of masonry construction (includes concrete block, poured concrete and stone-and-mortar).

3. For approximately how many low-rise housing units (detached, semi-detached or row housing) with basements are you responsible?

No. of Units _____

4. As best you can estimate how many basements (both insulated and uninsulated) within your area of responsibility suffer damage significant enough to cause serious concern for the homeowner and/or require remedial action.

↓ No. of Basements _____

- If you do not know an exact figure could you provide us with an estimate of the proportion of basements you think may be experiencing such problems?

Percent of Basements _____ %

- If you are not in a position to estimate the extent of the problem, please check the following box : ☐ Don't know

5. Approximately what proportion of existing basements in your municipality have been insulated? Try to exclude new construction in which case insulation is installed because of building code requirements (ie. not a retrofit).

↓ No. of Insulated Basements _____

- If you do not have an estimated figure, could you provide us with your feelings of the percentage of basements which have been insulated.

Percent of Basements Insulated _____ %

- If you are not in a position to estimate the extent of the problem, please check the following box: ☐ Don't know

-3-

6. Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?

- ☐ No —————→ Please return the questionnaire in the postage paid envelope provided. Thank you for your co-operation in this endeavour.
- ☐ Yes —————→ How many basements do you know of that have been damaged or exhibit an increase in damage as a result of an insulation retrofit?

No. of basements _____

SECTION C: Insulation-Related Basement Damage

ONLY IF YOU ANSWERED YES TO QUESTION 6 ABOVE SHOULD YOU ANSWER THE FOLLOWING QUESTIONS. The purpose of this section is to categorize any basement damage by highlighting factors which are relevant.

7. Identify damaged basements by the location and extent of insulation retrofit. "Full-depth" refers to insulation from top of basement walls to floor or footing level. "Partial-depth" refers to insulation from top of basement walls to part-way down the wall (usually 2 feet below grade).

- | | |
|---|---|
| ☐ interior partial-depth | ☐ exterior partial-depth |
| ☐ interior full-depth | ☐ exterior full-depth |
| ☐ floor insulation | |

8. Which housing type is subject to the damage being described above. Mark more than one type if applicable.

- ☐ detached (single family)
- ☐ semi-detached (duplex)
- ☐ row housing (townhouse)

9. When damage has occurred, which basement wall constructions are the most common? Mark more than one type if applicable.

☐ Poured concrete ☐ Concrete block
☐ Solid brick ☐ Rubble (stone and mortar)
☐ Other (specify) _____

10. The following is a partial list of possible damage exhibited by insulated basements. Mark as many damage types as applicable and add any of your own damage descriptions as required to identify problems you have encountered.

- Moisture related: ☐ dampness
 ☐ fungal growth, mildew, odors
- Surface deterioration
 - exterior: ☐ brick deterioration
 ☐ stone weathering
 ☐ salt leaching (white stains)
 - interior: ☐ drywall or panelling deterioration or staining
 ☐ rot of wood (non-structural)
 ☐ efflorescence (white build-up of chemical salt)
- Material deterioration:
 - : ☐ serious brick spalling
 - ☐ crumbling of stone
 - ☐ rot of wood components (potential structural damage)
- Wall damage: ☐ cracking
 ☐ significant movement of wall
 ☐ structural inadequacy
- Retrofit system: ☐ insulation degradation
 ☐ failure of fastening or support system
- Other types of damage: _____

11. Which causes do you feel are responsible for the damage listed in Question 10?

- ☐ Bad retrofit construction techniques
- ☐ Previously existing water leaks not remedied
- ☐ Previously existing air leaks not remedied
- ☐ Cooling of basement wall
- ☐ Cooling of soil adjacent to basement wall
- ☐ Insufficient understanding of moisture movement (vapour, condensation, etc.)
- ☐ General lack of maintenance of house structure and surroundings
- ☐ Other (specify) _____

12. Do you have specific case studies that could be of interest to this study?

☐ Yes

☐ No

13. We have a slightly more detailed questionnaire which enables a more accurate determination of problem areas relating to a specific basement. Would you be prepared to receive such a questionnaire?

☐ Yes → Have you filled in your name and address so we can contact you?

☐ No

PLEASE RETURN THIS QUESTIONNAIRE IN THE ENVELOPE PROVIDED.

THANK YOU FOR YOUR CO-OPERATION.

APPENDIX C
FORM LETTER FOR FRENCH MUNICIPALITIES



ALLEN-DRERUP-WHITE LTD.

C.1

low energy buildings — engineering, consulting, design and construction

334 King Street East, Studio 505
Toronto, Ontario M5A 1K8
(416) 863-1762

Cher Monsieur ou Madame:

La société ALLEN-DRERUP-WHITE Ltée entreprend une étude concernant l'isolation des immeubles résidentiel de basse-hauteur (détachée, attachée, en rangée). Si vous n'êtes pas au courant des sujets discuté ci-dessous, veuillez transmettre cette lettre au person qui convient le mieux.

Les "PROGRAMMES ENEGETIQUES DOMICILIARES" d'Energie, Mines et Resources Canada avancera bientôt une gamme de possibilités d'augmentation de l'isolant pour les propriétaires des maisons unifamiliales. En conséquence, cette étude s'entreprend avec le bout d'établir s'il y avait des problèmes qui ont surgit à cause de l'isolation des murs de fondation en béton ou en maçonnerie.

On prévoit que l'isolation d'un mur de fondation peut augmenter la risque de détérioration de ces murs. Quelques problèmes prévu se décrit ci-dessous:

1. Détérioration causée par la gelée dû au réduction des pertes thermiques au sol.
2. Augmentation de la détérioration hors-sol de la mur de fondation causée par l'action gel-dégel. Ceci peut arriver si l'isolant s'installe par l'intérieur, réduisant la température de la mur propre on hiver.
3. Des changements aux profilées de température et aux avenues de transmission de vapeur causée par l'installation de l'isolant peut augmenter la détérioration des surfaces intérieurs ou extérieurs en bois ou avancer la pourriture des supports ou charpentes en bois.

Les manifestations prévu peut avoir des conséquences sévère incluant la rupture de certaines éléments de la charpente, mais il existe très peu d'information substantif concernant une augmentation des problèmes causée par l'isolation des sous-sols.

La liste suivant se compose de quelque problems qui peut arriver:

C.2

- Problems d'humidité: (moississure, croissance des fongi, odeur)
- Détérioration des surfaces murals: (interieurs et exterieurs)
- Détérioration substantif des composants du bâtiment: (maçonnerie qui s'émiette, pourriture des poutres/solives en bois.
- Détérioration serieux des mûrs: (croissance des fissures, teneur insuffisant de structure)
- Problems de system d'isolation: (détérioration de l'isolant, faillite de la system de montage de l'isolant)

Si vous êtes en conaissance d'une sous-sol ou plusieurs sous-sols qui ont démontré evidence des détériorations nouvelles ou augmentées, causée par l'installation d'isolant, veuillez remplir la formule suivant et la retourner en l'enveloppe fournis pour que nous serons capable de vous contacter. Toute information demeurera strictement confidentiel.

Nom _____ N° de Tél _____

Position de fonctionnment:

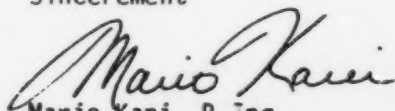
(Inspecteur des bâtiments,
Ingenieur, Greffier)

Adresse Postale:

_____ Code Postal _____

Merci de votre effort.

Sincèrement


Mario Kani, P. Ing.



ALLEN-DRERUP-WHITE LTD. 334 King St. E., Studio 505, Toronto, Ontario M5A 1K8
designers-builders and consultants, energy conservation, solar heating (416) 863-1762

Dear Sir or Madam:

Our firm, ALLEN-DRERUP-WHITE LTD., is conducting a study related to insulation of existing low-rise housing (detached, semi-detached, row housing). If you are not familiar with the issues discussed below, please pass this letter on to the person who is more suitable.

The Home Energy Program (HEP) of the Federal Department of Energy Mines and Resources will be promoting insulation retrofit options for the home owner, including basement retrofits. In preparation for this, a survey is being conducted to establish if any problems have occurred as a result of the insulation of masonry basements.

It has been predicted that insulating the foundation wall may significantly increase the risk of failure of the basement wall. Some predicted problems include the following:

1. Frost heave damage to the foundation wall due to reduction of heat loss to soil.
2. Increased above-grade freeze-thaw damage to the foundation wall. This can occur if interior insulation is applied, thus rendering the wall colder in winter.
3. Changes to temperature profiles and vapour transmission paths by insulating may cause increased damage to the interior or exterior surfaces or promote rot of supports of structural wood members.

While much predicted effects could have serious consequences including structural failure of various components, there exists very little substantiated information regarding increased problems as a result of insulation of basements.

The following is a list of some basement problems which may occur:

- Moisture problems - e.g. dampness, fungal growth, odour
- Surface deterioration of wall - interior and exterior
- Material deterioration of building components - masonry crumbling, rot of wood beams
- Serious wall damage - e.g. cracking, structural inadequacy
- Retrofit system problems - e.g. insulation degradation, failure of support of insulation

If you know of a basement or basements that show evidence of new or increased damage as a result of installation of insulation, please fill in the following information and return in the envelope provided, so that we will be able to contact you. All information will remain strictly confidential.

Name _____ Phone No. _____

Position in Municipality _____
(e.g. Building Official, Engineer, Clerk)

Mailing Address _____

_____ Postal Code _____

Thank you for your effort.

Sincerely yours,

Mario Kani, P.Eng.

APPENDIX D
LETTER CIRCULATED TO PUBLICATIONS

Basement insulation problems?

The engineering firm of Allen-Drerup-White Ltd. is undertaking an investigation of problems that have occurred after basement insulation has been installed. The study, which is being conducted for the Saskatchewan Research Council through the Canadian Ministry of Energy, Mines and Resources BETT Program, is to include masonry basements that have been insulated on the interior and/or exterior. We are interested in any basements that have exhibited new or increasingly severe problems since insulation has taken place. Problems include excessive condensation, surface deterioration (interior or exterior), rot of wood components (siding, joists, headers, sill plates), water leakage, and significant movement or structural inadequacy of the foundation wall. Problems with the insulation and its fastening system are also being considered.

If anyone comes across basements that have insulation-related problems or know of people who have knowledge relevant to this study, please contact me at Allen-Drerup-White Ltd., 334 King St. E., Suite 505, Toronto, Ont., Canada M5A 1K8.

—Mario Kani, Toronto, Ont.

APPENDIX E
DETAILED QUESTIONNAIRE

DETAILED QUESTIONNAIRE
FOR
SASKATCHEWAN RESEARCH COUNCIL SURVEY
REGARDING POST RETROFIT DAMAGE OF
INSULATED MASONRY BASEMENTS

"Damage" encompasses a wide range of basement problems: structural damage, material damage, moisture deterioration of surfaces and condensation problems, rot of header area and floor joists set into masonry walls, and failure of the retrofit system itself.

Please fill out one questionnaire per house with as much detail as possible.

When completed, please return to:

ALLEN-DRERUP-WHITE LTD.

334 King Street East, Suite 505
Toronto, Ontario M5A 1K8



A. Questionnaire Identification

E.2

Contact person _____
 Municipality _____
 Mailing Address _____

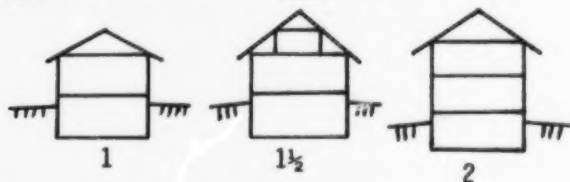
B. Basic House Data

This section identifies the house and gives details which are relevant to the whole house.

1. Address: _____

2. Type of House: ☐ detached ☐ semi-detached ☐ row housing

3. No. of Storeys: _____



4. Approximate age of house: _____

5. Approximate age of retrofit work: _____

Please check (✓) appropriate answer for questions 6 to 9.

6. Drainage related features:

*Does the house have perimeter weeping (drainage) tile at footing?

☐ yes
☐ no
☐ don't know

*The soil next to basement wall is:

same as original soil ☐
 well draining backfill ☐

*Approximate height of water table _____ metres (from grade level)

*The downspouts (if existing) are ☐ connected to perimeter tile
☐ routed to interior to
 floor drainage
☐ directed away from house at
 grade level

*The exterior of the basement wall:

- ☐ has not been dampproofed
- ☐ has been dampproofed (two thin layers of liquid tar)
- ☐ has been waterproofed (2 tar impregnated membranes cemented in place and covered by a layer of thick tar)
- ☐ don't know

7. House construction above grade

*Are the walls ☐ woodframe with exterior cladding of ☐ brick?
☐ siding?
☐ solid brick?
☐ concrete block?
☐ other? Please specify _____
☐ don't know

8. Heating System

*Conventional ☐: Is the heating supplied by ☐ forced air?
☐ hot water?
☐ electric
☐ baseboard?
☐ don't know

What is the fuel used? _____

Is there external combustion air supplied?

- ☐ yes
- ☐ no
- ☐ don't know

*Wood Heat ☐: Is the wood heater (wood stove, fireplace) the
☐ primary heating system?
☐ secondary heating system?

Is there external combustion air supplied?

- ☐ yes
- ☐ no
- ☐ don't know

*Other heating system ☐: Please specify:

9. Moisture-producing features

*Is there a humidifier attached to the furnace?

☐ yes
☐ no
☐ don't know

*Is there a laundry room in the basement?

☐ yes
☐ no
☐ don't know

*Is there an open sump or exposed soil in the basement?

☐ yes
☐ no
☐ don't know

*What is the occupancy level of the house?

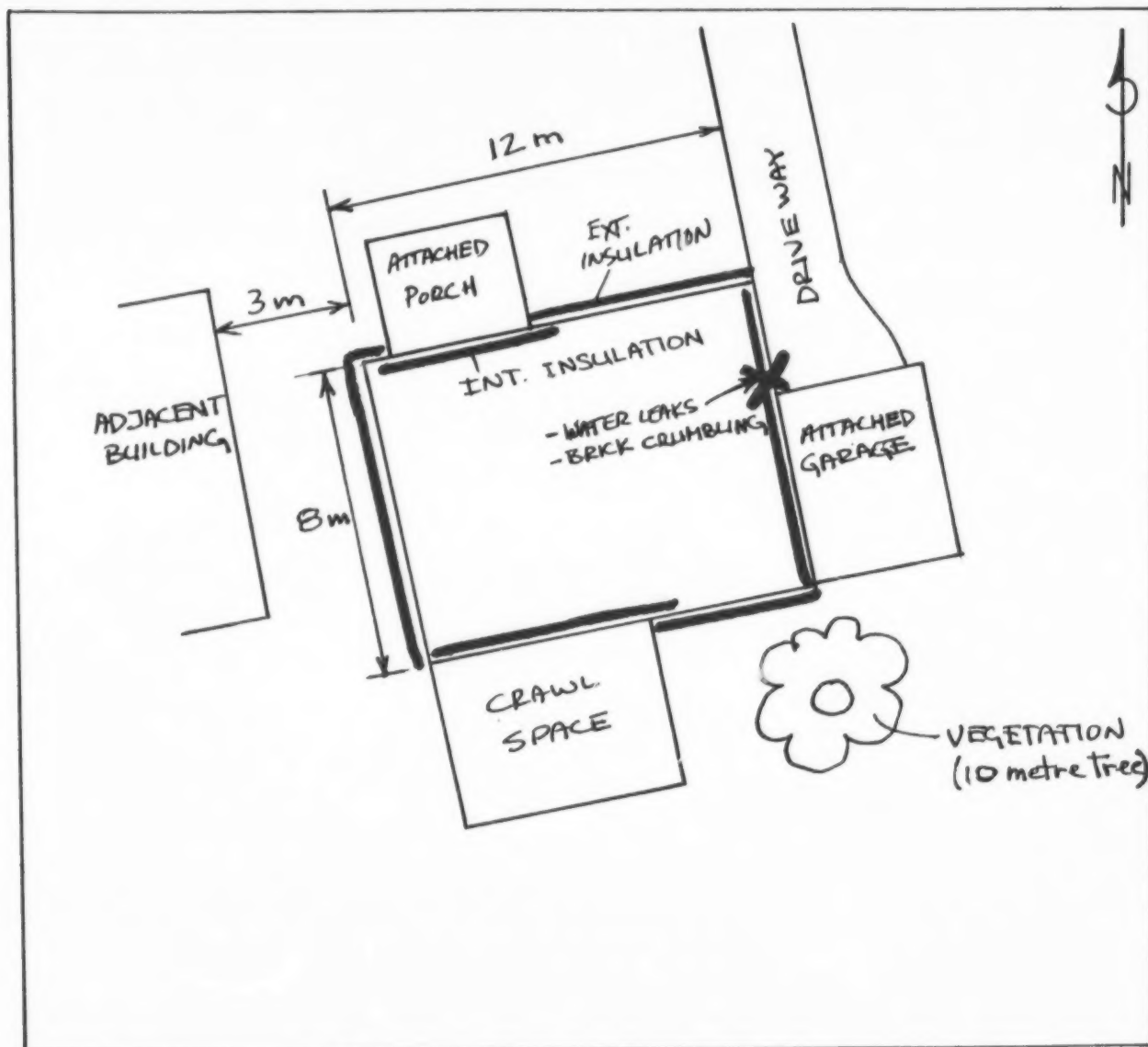
No. of adults ☐
 No. of children ☐
 Don't know ☐

C. The Site Plan

On the attached page please make a simple sketch of the basement. The following details should be indicated. (For sample sketch see attached completed diagram.)

1. Sketch the outline of the basement wall perimeter, remembering to orient the drawing properly according to the directional arrow. Note approximate dimensions of basement on sketch.
2. With a heavy line indicate the insulation installed along the wall, either inside or outside.
3. Mark any attached features, such as concrete sidewalks or driveways, porches, garages, crawlspaces.
4. Indicate major vegetation and adjacent buildings and give their approximate distances from the basement wall.
5. Mark problem area(s) along perimeter with a brief indication of the nature of damage.

Sketch basement according to description in questionnaire.

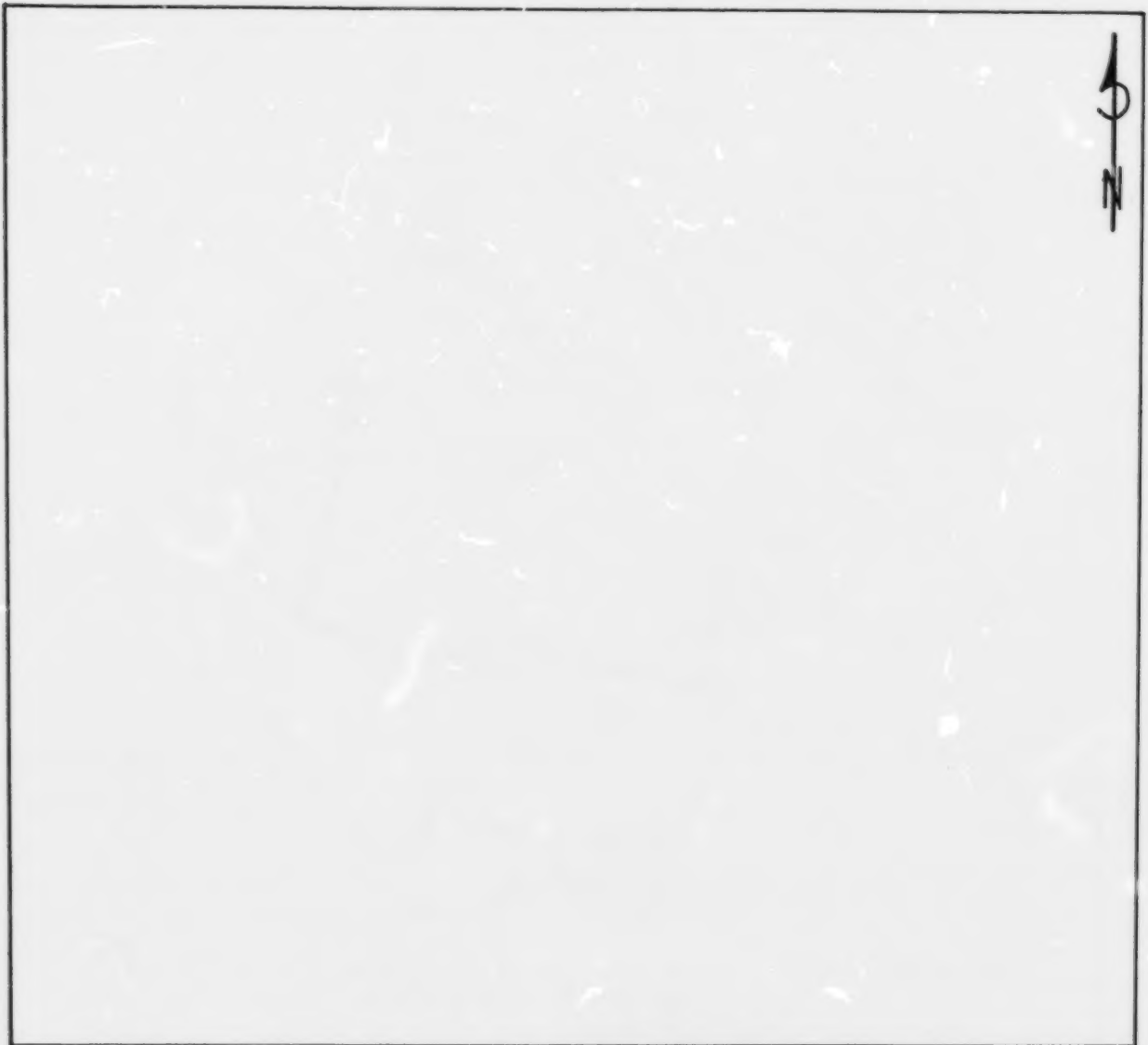


S A M P L E S K E T C H

C. Site Plan

E.6

Sketch basement according to description in questionnaire.



D. Description of Problem Area

The purpose of this section is to give some detail of the retrofitted basement and its surroundings at the cross section where a problem area exists. Attached is a diagram which requires relevant information to be added. Please make the appropriate choice of "keyword" for each heading below and enter the chosen keyword in the blank(s) under the same heading on the diagram. A completed sample diagram is provided. If none of the keywords for a particular heading are relevant to your building, please enter the term or description that you feel is appropriate.

Please note: the information on the diagram should relate to the area of the basement where a problem exists, not to the whole house.

HEADING	KEYWORD	CLARIFICATION
1. Roof Overhang	- None - Small - Significant - don't know	3" to 6" - more than 6"
2. Eavestroughing	- yes - no - don't know	
3. Downspout	- none - weeping tile - floor drain - grade level - don't know	- refers to "connected to <u>weeping tile</u>" - refers to "runs to interior to <u>floor drain</u>" - refers to "sheds water at grade level"
4. Grade Slope	- flat - away from house - toward house - don't know	
5. Construction of basement wall	- concrete block - solid brick - poured concrete - random rubble - coursed rubble - other - don't know	- field stones or irregular stone with mortar - regularly laid out stone with mortar - please specify
6. Exposure		- give dimension of <u>exposed basement height</u> above grade, in metres

HEADING	KEYWORD	CLARIFICATION
7. Basement Temperature	- heated - unheated	Give basement temperature, if known
8. Joist Support	- sill plate - masonry ledge - wood plate - fire cut - other - don't know	- typical wood frame construction - bearing directly on top of foundation wall - bearing on wood embedded in masonry - joist directly embedded in masonry - please specify
9. Interior Insulation	- no - yes	- if "no" skip to Section 10
*Dampproofing	- yes - no - don't know	- interior, to grade, directly applied to wall
*Insulation	- fibreglass batt - blue styrofoam - white beadboard - other - don't know	- please specify
*Insulation level		- give RSI value of insulation added ($RSI = 0.172 \times R\text{-value}$)
*Fastening System	- none - wood - metal studs - strapping - bonded - other - don't know	- strapping or studs fastened to wall - metal or wood strapping on interior side of insulation - directly to wall
*Vapour Barrier	- yes - no - don't know	- on warm side
*Finish	- none - gypsum board - wood panelling - other - don't know	- please specify
*Insulation Height		- give distance from top of foundation wall to bottom of insulation, in metres

HEADING	KEYWORD	CLARIFICATION
10. Exterior Insulation	- no - yes	- if "no" skip to Section 11
*Insulation	- blue styrofoam - white beadboard - high density fibreglass	- should be good quality - board with draining properties
*Insulation Level		- give RSI - value of insulation added ($RSI = 0.172 \times R\text{-value}$)
*Fastening	- none - connectors - strapping - bonded - other - don't know	- at top of wall - metal or wood embedded on exterior of insulation - directly to wall - please specify
*Finish	- none - parging - stucco - wood - plastic sheeting - other - don't know	- cement mortar reinforced with metal lath - polymerized fibre (reinforced) cement mortar - pressure treated boards or plywood - please specify
*Insulation Height		- give distance from top of foundation wall to bottom of insulation, in metres
11. Floor Insulation	- no - yes	- if "no", skip to Section 12
*Dampproofing	- yes - no - don't know	- polyethylene film, foil, tar or good quality paint
*Insulation	- blue styrofoam - white beadboard - rigid fibreglass - other - don't know	- please specify
*Insulation Level		- give RSI value of insulation added ($RSI = 0.172 R\text{ value}$)

HEADING	KEYWORD	CLARIFICATION	E.10
11. (cont'd)			
*Fastening	- none - wood studs - strapping	- metal or wood strapping on the top side of the insulation - please specify	
	- other - don't know		
*Finish	- none - tiles - paint - carpet - hardwood - other - don't know	on wood subfloor	

12. Problem Area(s)

With arrows indicate problems and identify it (them) with brief description. Suggested problems are:

Basement

*Moisture related: condensation
water leaks
odour

*Weatherizing: air leaks

*Surface deterioration: - exterior:
brick deterioration
stone weathering
salt leaching (white stains)

- interior:
drywall staining
rot of wood
mildew
efflorescence (white buildup of chemical
salt)

*Material deterioration - serious brick spalling
- crumbling of stone
- rot of wood component
(e.g. joist ends or joist supports)

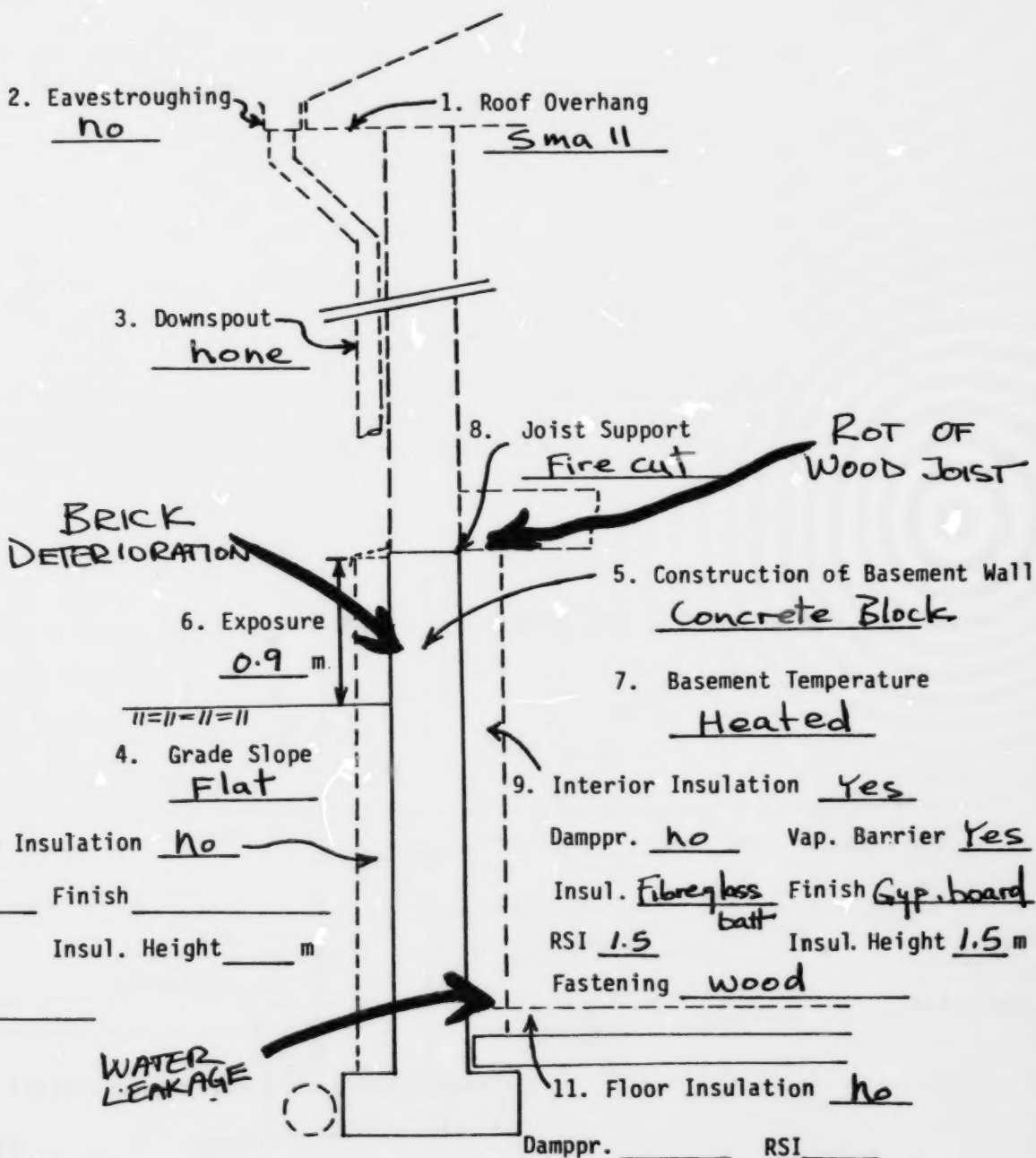
*Wall damage - cracking
- significant movement
- structural inadequacy

Retrofit System

*Insulation degradation
*Failure of fastening or support system
*Poor detailing - flashing
- construction techniques

Address 1 REGINA ST.

E.11

D. Description of Problem AreaS A M P L E

12. Problem Areas

Identify problem areas on drawing by marking location and specifying type of damage.

D. Description of Problem Area

E.12

2. Eavestroughing _____

1. Roof Overhang _____

3. Downspout _____

8. Joist Support _____

5. Construction of Basement Wall _____

6. Exposure _____ m

7. Basement Temperature _____

4. Grade Slope _____

9. Interior Insulation _____
 Damppr. _____ Vap. Barrier _____
 Insul. _____ Finish _____
 RSI _____ Insul. Height _____ m
 Fastening _____

10. Exterior Insulation _____
 Insul. _____ Finish _____
 RSI _____ Insul. Height _____ m
 Fastening _____

11. Floor Insulation _____
 Damppr. _____ RSI _____
 Insul. _____ Finish _____
 Fastening _____

12. Problem Areas
 Identify problem areas on drawing by marking location and specifying type of damage.

13. In your or the homeowner's opinion, how was the wall, floor or basement different before retrofitting (in terms of problem areas):

14. In your opinion, is the problem a direct result of retrofitting. If yes, can you identify the cause?

Construction techniques

Reduced heat loss

Increased moisture movement

Other

15. Do you have any documentation of the basement problems, such as a report, photographs, notes, analysis? If so, please enclose copies of such information when forwarding questionnaire.

16. Would you be prepared to have a researcher investigate the building?

17. Do you have any comments on improving insulation retrofit techniques?

18. Please forward completed questionnaire to:

ALLEN-DRERUP-WHITE LTD.

STUDIO 505

334 KING ST.E.

TORONTO, ONTARIO

M5A 1K8

9

THESE ARE THE ONLY TWO
REMAINS OF THE ORIGINAL
AND REMAINING PART OF THE

ORIGINAL
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APPENDIX F
ANALYSIS OF RESPONSES FROM BUILDING OFFICIALS

RESPONSES TO INITIAL QUESTIONNAIRE

Notes:

1. All returned questionnaires have been included except those completely blank and one referring only to preserved wood foundations. There has been no "editing" of the responses, however inappropriate they appeared.
2. The questionnaire, in Appendix A, gives the full wording of the questions.
3. The questionnaires were grouped by the responses to questions 6 and 3, to show the variance, if any. The groups are:
 - A. ALL - all questionnaires.
 - B. Q.6 = YES
ALL - all questionnaires with a response to question 6 of Yes.
 - C. Q.6 = NO
ALL - all questionnaires with a response to question 6 of No or blank.
 - D. Q.6 = YES &
Q.3 = NUMBER - all questionnaires with a response to question 6 of Yes and to question 3 of a number, not number per year etc.
 - E. Q.6 = NO &
Q.3 = NUMBER - as in D, except with a response to question 6 of No or blank.
4. For questions 7 through 11, the respondents were asked to mark more than one type if applicable. The "non-blank responses" entry is the number of questionnaires where at least one option was marked for that question. These questions were only to be answered by those who answered question 6 with Yes, however several others also responded.
5. The numerical responses to questions 3 to 6 are given in the "Value of Responses" tables. The median value is the value of the response where at least half the responses are less than or equal to it. The mean value is the sum of the responses divided by the count of the responses.

COUNT OF RESPONSES

F.2

QUESTIONNAIRE GROUP

	ALL	Q.6=YES ALL	Q.6=NO ALL	Q.6=YES & Q.3=NUMBER	Q.6=NO & Q.3=NUMBE
Q.3 How many low-rise housing units with basements are you responsible for?					
- Number	94	10	84	10	84
- Other					
# per year	22	6	16	0	0
# in year	8	0	8	0	0
miscellaneous	8	0	8	0	0
blank	16	0	16	0	0
Q.4 How many basements within your area of responsibility suffer damage significant enough to cause serious concern?					
- Number	56	5	51	4	31
- %	44	9	35	5	22
- Don't know	60	2	58	1	39
- Blank	1	0	1	0	0
Q.5 What proportion of existing basements in your municipality have been insulated? (Exclude new construction)					
- Number	23	6	17	4	14
- %	83	10	73	6	48
- Don't know	52	3	47	1	28
- Blank	2	0	2	0	0
Q.6 Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?					
- No	127	0	127	0	82
- Yes	16	16	0	10	0
- Number given	12	12	0	7	0
- Blank	5	0	5	0	2

TABLE F.1

COUNT OF RESPONSES

QUESTIONNAIRE GROUP

	ALL	Q.6=YES ALL	Q.6=NO ALL	Q.6=YES & Q.3=NUMBER	Q.6=NO & Q.3=NUMBER
Q.7 Extent of insulation retrofit	17	14	3	8	1
non-blank responses	4	4	0		0
interior partial-depth	14	11	3	3	1
interior full-depth	0	0	0	6	0
floor insulation	0	0	0	0	0
exterior partial-depth	0	0	0	0	0
exterior full-depth	0	0	0	0	0
Q.8 Housing type damaged	19	16	3	10	1
non-blank responses	19	16	3	10	1
detached (single family)	7	6	1	10	0
semi-detached (duplex)	5	4	1	4	0
row housing (townhouse)				2	0
Q.9 Basement wall constructions	21	16	5	10	2
non-blank responses	9	7	2	4	0
poured concrete	0	0	0	0	0
solid brick	17	14	3	9	2
concrete block	2	2	0	1	0
rubble (stone and mortar)					
Q.10 Types of damage exhibited	26	16	10	10	6
non-blank responses	16	10	6	7	6
moisture related: - dampness	12	7	5	5	4
- mildew, odours					
surface deterioration:	4	3	1	2	0
-exterior: brick deterioration	1	1	0	1	0
stone weathering	10	4	6	3	4
salt leaching	11	7	4	5	3
-interior: drywall or panelling	6	3	3	2	2
rot of wood	9	5	4	5	3
efflorescence					

TABLE F.1

(cont'd)

COUNT OF RESPONSES (cont'd)

QUESTIONNAIRE GROUP

	ALL	Q.6=YES ALL	Q.6=NO ALL	Q.6=YES & Q.3=NUMBER	Q.6=NO & Q.3=NUMBER
material deterioration	1	1	0	1	0
- serious brick spalling	2	1	1	1	1
- crumbling of stone	6	4	2	3	2
- rot of wood components	15	9	6	5	3
wall damage: - cracking	13	12	1	8	1
- significant movement	3	2	1	2	0
- structural inadequacy					
retrofit system:					
- insulation degradation	5	5	0	2	0
- fastening or support system	3	2	1	1	1
other	10	7	3	4	1
Q.11 Causes responsible for damage					
non-blank responses	23	16	9	10	5
bad retrofit techniques	9	6	3	4	2
existing water leaks not remedied	9	6	3	4	2
existing air leaks not remedied	3	1	2	1	2
cooling of basement wall	7	6	1	4	0
cooling of soil adjacent to basement wall	12	9	3	4	1
insufficient understanding of moisture movement	13	8	5	5	3
lack of maintenance of house structure	6	3	3	1	2
other	10	7	3	5	1
Q.12 Have specific case studies					
non-blank responses	26	16	10	10	7
yes	4	3	1	2	1
no	22	13	9	8	6
Q.13 Prepared to receive detailed questionnaire					
non-blank responses	24	13	11	9	8
yes	15	8	7	4	7
no	9	5	4	5	1

F.4

TABLE F.1

VALUE OF RESPONSES

F.5

GROUP: ALL

	COUNT OF RESPONSES	VALUE OF RESPONSES			
		MAX.	MEDIAN	MIN.	MEAN
Q.3 How many low-rise housing units with basements are you responsible for?					
- Number	94	45,000	2,200	0	4,082
- Other					
# per year	22	1,000	200	3-15	274
# in year _____	8	7,039	150	25	1,221
miscellaneous	8				
blank	16				
Q.4 How many basements within your area of responsibility suffer damage significant enough to cause serious concern?					
- Number	56	250	0	0	16
- %	44	50	1	0	5
- Don't know	60				
- Blank	1				
Q.5 What proportion of existing basements in your municipality have been insulated? (Exclude new construction)					
- Number	23	12,000	150	0	730
- %	83	100	30	0	38
- Don't know	52				
- Blank	2				
Q.6 Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?					
- No	127				
- Yes	16				
- Number given	12	12	3	1-2	4.3
- Blank	5				

TABLE F.2

VALUE OF RESPONSES

F.6

GROUP: Q.6 = YES, ALL

	COUNT OF RESPONSES	VALUE OF RESPONSES			
		MAX.	MEDIAN	MIN.	MEAN
Q.3 How many low-rise housing units with basements are you responsible for?					
- Number	10	41,000	1,600	0	5,604
- Other					
# per year	6	1,000	250	3-15	316
# in year _____	0				
miscellaneous	0				
blank	0				
Q.4 How many basements within your area of responsibility suffer damage significant enough to cause serious concern?					
- Number	5	200	4-5	0	44
- %	9	50	2	1	8.4
- Don't know	2				
- Blank	0				
Q.5 What proportion of existing basements in your municipality have been insulated? (Exclude new construction)					
- Number	6	12,000	75	6	2,101
- %	10	65	30	1	35
- Don't know	3				
- Blank	0				
Q.6 Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?					
- No	0				
- Yes	16				
- Number given	12	12	3	1-2	4.3
- Blank	0				

TABLE F.2

VALUE OF RESPONSES

F.7

GROUP: Q.6 = NO, ALL

	COUNT OF RESPONSES	VALUE OF RESPONSES			
		MAX.	MEDIAN	MIN.	MEAN
Q.3 How many low-rise housing units with basements are you responsible for?					
- Number	84	45,000	2,100	0	3,909
- Other					
# per year	16	1,000	200	20	258
# in year _____	8	7,039	150	25	1,221
miscellaneous	8				
blank	16				
Q.4 How many basements within your area of responsibility suffer damage significant enough to cause serious concern?					
- Number	51	250	0	0	14
- %	35	30	1	0	4.1
- Don't know	58				
- Blank	1				
Q.5 What proportion of existing basements in your municipality have been insulated? (Exclude new construction)					
- Number	17	1,000	150	0	234
- %	73	100	30	0	38
- Don't know	47				
- Blank	2				
Q.6 Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?					
- No	127				
- Yes	0				
- Number given	0				
- Blank	5				

TABLE F.2

VALUE OF RESPONSES

F.8

GROUP: Q.6 =YES & Q.3 = NUMBER

	COUNT OF RESPONSES	VALUE OF RESPONSES			
		MAX.	MEDIAN	MIN.	MEAN
Q.3 How many low-rise housing units with basements are you responsible for?					
- Number	10	41,000	1,600	0	5,604
- Other					
# per year					
# in year _____					
miscellaneous					
blank					
Q.4 How many basements within your area of responsibility suffer damage significant enough to cause serious concern?					
- Number	4	200	3	0	54
- %	5	50	1-5	2	13
- Don't know	1				
- Blank	0				
Q.5 What proportion of existing basements in your municipality have been insulated? (Exclude new construction)					
- Number	4	200	20-30	6	77
- %	6	50	30	1	32
- Don't know	1				
- Blank	0				
Q.6 Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?					
- No	0				
- Yes	10				
- Number given	7	12	3	1-2	3
- Blank	0				

TABLE F.2

VALUE OF RESPONSES

GROUP: Q.6 = NO & Q.3 = NUMBER

	COUNT OF RESPONSES	VALUE OF RESPONSES			
		MAX.	MEDIAN	MIN.	MEAN
Q.3 How many low-rise housing units with basements are you responsible for?					
- Number	84	45,000	2,100	0	3,909
- Other					
# per year					
# in year _____					
miscellaneous					
blank					
Q.4 How many basements within your area of responsibility suffer damage significant enough to cause serious concern?					
- Number	31	250	0	0	14
- %	22	20	1	0	3.3
- Don't know	39				
- Blank	0				
Q.5 What proportion of existing basements in your municipality have been insulated? (Exclude new construction)					
- Number	14	1,000	100	0	203
- %	48	100	30	0	38
- Don't know	28				
- Blank	0				
Q.6 Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?					
- No	82				
- Yes	0				
- Number given	0				
- Blank	0				

TABLE F.2

APPENDIX G
COMMENTS OF BUILDING OFFICIALS

Question 4: 'As best you can estimate, how many basements (both insulated and uninsulated) within your area of responsibility suffer damage significant enough to cause serious concern for the homeowner and/or remedial action.'

Less than 3 per year obtain permits to do repair work.

Our inspection staff indicate that frost related problems due to foundation insulation are not a problem in our municipality. Serious problems of this nature would come to our attention through complaints.

Question 5: 'Approximately what proportion of existing basements in your municipality have been insulated? Try to exclude new construction in which case insulation is installed because of building code requirements (i.e. not a retrofit).'

This is a common misconception. The National Building Code of Canada does not specifically require basement insulation. You should distinguish between CMHC standards, Ontario Code, etc.

Most of the retrofit would be done without our knowledge therefore we do not have any statistics to provide information. (We have witnessed no damage to new construction in our area.)

Question 6: 'Are you aware of any cases of basements that have been damaged as a result of an insulation retrofit?'

None that I am positive have been damaged as result of insulation, but I suspect some have.

Increased frost may damage in future.

Sometimes it is difficult to tell if the damage results from the completion of a basement: was it there when the finishing commenced or was a combined result of many factors included in Question 11.

8 or 10 that I know of that came to me for advice - others went back to contractors for the foundation.

Question 8: 'Which housing type is subject to the damage being described above. Mark more than one type if applicable.'

It could happen on any type on the drive-way side. We have 11700 degree days here, frost penetrates to 5-7 feet below drives and at the foundation wall but damage occurs in the 2 to 4 feet below grade.

Question 10: 'The following is a partial list of possible damage exhibited by insulated basements. Mark as many damage types as required to identify problems you have encountered.'

Found that in some cases ponding of water occurred adjacent to the foundation walls during wet seasons because of poor drainage resulting in excessive ice and inward frost heave. This of course also occurred on some of the housing with non-insulated concrete walls.

Basement wall insulation should preferably be done on outside of wall (costly to retrofit) or backfill with moisture resistant material.

My main concern would be frost damage by soil expansion of insulated masonry foundation walls, over a period of time.

Most of the above problems have been experienced locally in uninsulated basements (our problem is dampness not cold).

Moisture and condensation on the inside of vapour barrier at the bottom 3 feet of wood basement walls.

Poor quality workmanship in the construction of foundations is a major problem. Of the dwellings mostly affected by elements, properly constructed foundations seem to have far less problems.

Frost heave occurring in basement garages when the balance of the basement area has been insulated.

Insulation installed on the interior of a cement block wall causes frost movement inward and thus allows cracks in block joints allowing water and cold to enter. The wall eventually is weakened and causes a danger of crumbling. Blue insulation should be installed on the exterior of cement block walls for best results.

Frost build up on foundation walls, damaging insulation when exterior temperatures increase.

Question 10 (cont'd)

Expansion of panelling.

It depends on the amount of heat that is provided in the basement and whether there is a cold air return from the basement, so the basement or cellar can be heated without leaving the cellar door open as avenue of return air to the first floor grilles back to the furnace.

Second and third row of block from top being pushed inward by frost action.

Question 11: 'Which causes do you feel are responsible for the damage listed in Question 10?'

Also due to backfilling techniques on new and old construction. Also lack of weeping tile in older home retrofits.

Frost susceptible soils and poor grading.

Wrong location for insulation.

Ice lense formed in heavy clay soils, inadequate exterior drainage, failure of perimeter drain.

Following too closely laid down recommendations from overqualified R&P's.

Drainage may be to wall instead of away from it.

General:

It is difficult to blame insulation for cracked foundation walls when there are so many other possible causes. In all cases of interior insulation, however, all foundation failures are concealed from view until they become apparent through leakage, etc.

Unfortunately statistics have not been maintained on the information you seek, but new and existing (older) homes do suffer to minor extent from poor construction practices. Poor practice is almost always of the homeowners doing in the instance of retrofit and it is only after the fact that he might consider assistance from a municipal official. In this town, extensive new housing is in progress, all with poured concrete foundations. Emphasis seems to be placed on exterior rigid insulation without any noticeable detrimental effect to date.

It is my opinion that a significant increase in basement insulation would be quite risky because if you lose the buffering action of a minimal heat loss, the unilateral pressures will become critical in some cases, i.e. heavy soil or wet soil conditions.

The major problem found here was poor soil drainage away from the walls of the dwellings. Due to the high soil water excessive ice developed from freezing tight to the insulated basement walls resulting in the inward heave. The problem was resolved by the regrading of the soil adjacent to the foundation walls. This applied to both insulated and non-insulated walls.

A few cases of foundation wall movement due to swelling of soil conditions from seasonal moisture changes (variable water table depths) due to poor or no lateral drains at foundation level and high swelling clays - not common. Of all new construction on new homes and in new retrofits (say the last 5 years or less) the Provincial Code called for dampproofing of the interior face of foundation walls prior to placing wood framing against these walls. There appears some problem here where water condensation develops between the inside face of concrete and a polythene moisture barrier.

Moisture builds up at the base of the wall and, if excessive, damages the finish inside the room by staining, deterioration of gyproc, etc., and also wood framing. The condensation occurs on either or both sides of the polythene dampproofing depending on the vapour proofing or dampproofing of the external concrete foundation wall and on the vapour proofing of the interior face of the wood stud walls which are against the concrete foundation wall. It is very important that a high quality vapour barrier be provided on the inside (well placed and sealed).

I feel that insulating below grade on the outside (including dampproofing) would help or totally resolve this problem with no insulation placed on the inside face of the foundation walls.

This would depend on the location of the dewpoint temperature parameters. Based on the external and internal soil and air temperatures and would have to be calculated and researched. For example; use of, say, 3 inch thick styrofoam plastic insulation applied over the surface of the exterior face of the concrete, masonry, etc. Foundation wall with a protective membrane to resist backfilling abrasion of forces. This would be an interesting research project.

This exercise is very interesting. I do believe that serious problems will occur in some areas and especially if the exterior surface of the basement wall is not absolutely smooth and will allow frozen ground to get a grip on the structure.

I personally feel that there is some need for study of basement insulation. I have experienced problems with condensation forming on the insulation side of the vapour barrier on new construction, especially during the hot summer weather, when even a de-humidifier does not fully eliminate this problem.

The matter is simple: insulate outside.

In 1981 we had a bad year, very cold and windy. 6 or 8 foundations cracked and some pushed in 1/2" to 1".

For partial depth interior insulation the most common problem is related to the difficulty of sealing the insulation against the wall. The result, of course, is condensation of moisture behind the insulation causing mildew and eventual damage to interior finish.

We also checked with some home owners to see if we could find any cases of basement problems and we could not find any.

Winter temperatures in this municipality are generally not sufficiently low to cause problems.